EVALUATION OF ACCURACY OF DENTAL IMPLANT POSITIONING PLACED USING DIGITALLY PLANNED 3D PRINTED SURGICAL STENT- A CASE SERIES

Dissertation submitted to

THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY

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MASTER OF DENTAL SURGERY

BRANCH III

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THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY

CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"EVALUATION OF ACCURACY OF DENTAL IMPLANT POSITIONING PLACED USING DIGITALLY PLANNED 3D PRINTED SURGICAL STENT- A CASE SERIES"** is a bonafide record and genuine research work done by me under the guidance of **Dr.M.VEERABAHU,M.D.S.,FIBOMS** Professor and Head, Department of Oral & Maxillofacial Surgery, Ragas Dental College and Hospital, Chennai.

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This Dissertation is submitted to **THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY,** in partial fulfillment for the award of the Degree of **MASTER OF DENTAL SURGERY – ORAL AND MAXILLOFACIAL SURGERY, BRANCH III.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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On verification with the website unkund.com for the purpose of plagiarism check, the uploaded thesis file from introduction to conclusion contains 8**% of plagiarism**, as per the report generated and the same is enclosed in Annexure – II.

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************** ***Vazhga valamudan*** ***************

ABSTRACT

PURPOSE: The aim of study is to evaluate the accuracy of dental implant positioning placed using digitally planned 3D printed surgical guide.

MATERIALS AND METHOD: The study was conducted in the department of Oral and Maxillofacial Surgery, Ragas Dental college, Chennai, Tamilnadu. 15 implant sites in 4 patients irrespective of gender (two males and two females) were selected based on the inclusion criteria. These patients, who presented to the department of Oral and maxillofacial surgery Ragas Dental College and hospital with a complaint of partial or complete edentulism with a desire of fixed prosthesis, were included in the study. Pre-operative CBCTs were taken. Virtual planning was performed through blue sky bio software and surgical guide was prepared. Guides were fabricated through Stratasys Eden 260vs computer 3D printer by polyjet printing technology. SS316 cylindrical drill sleeves were prepared. Drilling was done by placing the surgical guides through the information gained from virtual planning. Depth control system was used. A drill was inserted in the drill sleeve of master sleeve upto the physical stop of drill shaft and the next size sleeve was placed where the drill was completely inserted in to the master sleeve for achieving the implant depth. This was done in a sequential order and the final drill was placed directly in to the master sleeve. After six months, postoperative CBCT were taken. A Virtual planning was performed in preoperative CBCT and post operative CBCT were converted into virtual 3D models using DICOM to Print

(D2P) software. These 3D models were superimposed using Geomagic Freedom software and accuracy of the angulation of the implant had been evaluated.

RESULTS: The results from the study revealed that the mean value for deviation of the angulation at crest was 6.9885 degrees and the standard deviation was 11.38088 degrees. The mean value for deviation of the angulation at apex was 6.8292 and the standard deviation was 11.09377. The mean value for the deviation at crest was 0.6623mm and the standard deviation was 1.15892mm. The mean value for the deviation at apex was 0.6131mm and the standard deviation was 0.8831mm.

CONCLUSION: From the results of the study we would like to conclude that the placement of dental implants using digitally planned surgical guides is within clinically acceptable limits. It further ensures minimal or virtually nil damage to the relevant anatomical structures and makes implant placement less difficult for beginners.

Key words: **Surgical guides, Virtual planning, DICOM, CBCT.**

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Introduction

INTRODUCTION

The term Edentulism as per glossary of prosthodontics terms (GPT) is defined as the state of being edentulous without natural tooth.

Tooth loss can lead to the following consequences, which may include the following:

- Dissatisfaction with appearance and loss of confidence.
- Mental anxiety.
- Changes in facial features, loss of bone and gingival tissue, difficulty eating and speaking, poor nutrition.
- Pain, distress and relaxation problems.
- Embarrassed and/or ashamed to seek dental treatment.
- Financial burden for costs of possible treatment options.

There are various methods to replace the tooth loss or to treat edentulism namely

COMPLETE DENTURE: It is a removable dental prosthesis that replaces the single or multiple missing teeth; the removable denture can be readily inserted and removed from the mouth by the patient.

REMOVABLE PARTIAL DENTURE: It is a removable dental prosthesis that replaces the single or multiple missing teeth; the removable partial denture can be readily inserted and removed from the mouth by the patient.

FIXED PARTIAL DENTURE is referred to any dental prosthesis that is luted, screwed, or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implants/abutments that furnish the primary support for the dental prosthesis and restoring teeth in a partially edentulous arch; it cannot be removed by the patient.

IMPLANT is referred to any object or material, such as an alloplastic substance or other tissue, which is partially or completely inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes.

DEFINITION

Dental Implant is defined as a prosthetic device made of alloplastic material implanted into the oral tissues beneath the mucosal or/ & periosteal layer &/or within the bone to provide retention & support for a fixed or removable dental prosthesis; a substance that is placed into or / & upon the jaw bone to support a fixed or removable dental prosthesis.

Advantages of dental implants

- Lack of involving adjacent teeth in prosthetic management.
- Preventing root canal treatment and tooth preparation in adjacent healthy tooth.

- It has better longevity when compared with other restorative procedures if properly placed and maintained.
- It restores bite force.
- It is biocompatible.
- It prevents bone loss.
- It enables natural speech.
- It provides better esthetics.

Disadvantages of dental implants

- Require a higher up-front cost than a bridge or dentures. However, the longevity of results makes this approach more cost-effective.
- In order to replace missing teeth with implants and provide implant supported restorations such as or dentures, it is necessary to undergo a minor oral surgery.
- Time period for delivering the final prosthesis is conventionally longer than FPD/RPD; although immediate loading is possible with dental implants, the placed implants fulfills certain stringent clinical parameters.
- Lack of bone at implant site will require additional bone augmentation procedure.
- Contraindications in certain clinical conditions like,

1. I.V bisphosphonate,
2. Uncontrolled diabetes,
3. Smoking,
4. Children whose growth is yet to increase.

IMPLANT PLANNING CONSIDERATIONS

Bone quality and quantity plays the major role in implant planning and placement. Implants would fail if a patient has;

- Inadequate labiolingual width.
- Inadequate vertical maxillary alveolar bone.
- Inadequate vertical mandibular alveolar bone.

Angulation of the implant is another crucial factor that has to be considered while placing an implant. If the angulation is inappropriate the implant may damage the neighbouring vital anatomic structures and the root of the adjacent teeth. Improper angulation leads to lack of esthetic replacement of prosthetic crown or bridge in addition it may contribute to gingival recession as well.

The minimum required distance between the implant and the buccal plate is 1mm, lingual plate is 1 mm, maxillary sinus is 1 mm, nasal cavity is 1mm and in incisive canal midline of the maxilla is to be avoided.

Mesiodistal dimension: The implant body should not be closer than 1.5 mm to an adjacent root surface and not be closer to 3 mm to an adjacent implant.

In relation to the inferior alveolar canal, the implant has to be placed 2mm from superior aspect of bony canal.

In relation to mental nerve, the implant has to be placed 5mm anteriorly to mental foramen.

Orofacial dimension:

Anterior region: The implant shoulder is positioned 1 mm palatal to the point of emergence of adjacent teeth, aiming for at least 1.5 mm bone thickness at the labial side.

Posterior region: The implant is positioned in the centre of the future restoration, aiming for at least 1.5 mm of bone thickness at the buccal and palatal/lingual side.

Corono-apical dimension: The implant shoulder is positioned 3 mm apical to the emergence of the future restoration with an expected biologic width of also 3 mm, being the equivalent of 1 mm apical of the cementoenamel junction of the contralateral tooth in patients without gingival recession.

The minimum integration time in the region of anterior mandible is 3 months, posterior mandible is 4 months, anterior and posterior maxilla is 6 months & bone graft is 6-9 months.

CHALLENGES IN IMPLANT PLANNING

Imaging of the implant site will have to be done to determine bone density and bone quantity, to evaluate the approximation of vital anatomical structures and to estimate the dimensions, number, location, orientation, prognosis of the implant to be inserted, identify underlying bony pathologies, undercuts and concavities. The requirement for additional bone augmentation should be evaluated.

In 2D imaging, certain parameters cannot be assessed such as:

a) Labiolingual width,

b) Exact position of vital anatomical structures,

c) Quality and quantity of available bone.

The objectives of diagnostic imaging depend on the amount and type of information required and the treatment period rendered. The timing and type of imaging modality to be used depends on the integration of the phases mentioned below:

PHASE I (Pre-surgical implant imaging)

To determine the bone quantity and quality and an approximation of the implant site with the critical structures, as well as to plan implant orientation, all necessary surgical information would be obtained in this phase.

PHASE II (Surgical and intraoperative implant imaging)

Along with analysis the optimal position and orientation of the implant, intraoperative implant imaging helps evaluate the healing and integration of surgery sites. The correct position of the abutment and prosthesis fabrication will have to be ensured in this phase.

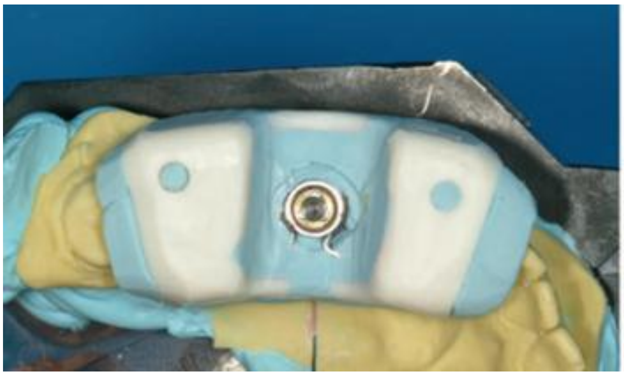
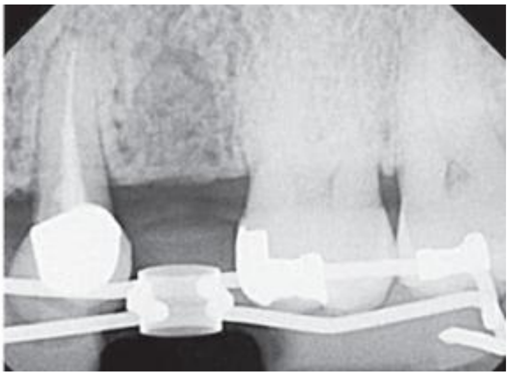
PHASE III (Post-prosthetic implant imaging)

This phase starts from the placement of the implant and lasts as long as the implant remains in the jaw. The radiographic sequence for phase III imaging is post-prosthetic imaging, followed by recall and maintenance imaging and an evaluation of alveolar bone change.

SURGICAL GUIDES:

Cast-based Guided Surgical Guide

The surgical guide is a combination of an analog technique done along with bone sounding and the use of periapical radiographs in a conventional flapless guided implant surgery. The periapical radiograph is modified using digital software to help in transposition of root structure onto the cast. The cast is then sectioned at the proposed implant site, and bone-sounding measurements are transferred to help in orientation of the drill bit to perform a cast osteotomy. A laboratory analogue is placed in the site, and a guide sleeve consistent with the implant width is modified using wires that are used to create a framework around the teeth. Vinyl polysiloxane occlusal registration material is used to form the super structure.

CAD/CAM-based surgical guide

They are appliances that are computer designed and are fabricated from acrylic resin by a process called Stereolithography. The surgical guides contain steel sleeves with a predefined diameter to guide the drills during the osteotomy process. There are different types of surgical guides such as a pilot guide, which allows the clinician to create the initial osteotomy. After the pilot osteotomy is created, the guide is removed and the rest of the process is done free handed. Other guides allow completing all the osteotomy processes by using the entire drill sequence; however, the implant is placed free handed, whereas there are others that require a guide that allows going through all the drilling sequence and placement of the implant. Some protocols include depth control systems that allow the surgeon to control vertical preparation by using a stop at the drill or at the sleeve insert levels. In addition, surgical guides can be categorized according to the type of stabilization they have such as teeth, bone, or soft tissue.

The advantages of CAD-CAM based surgical guide are as follows,

- With good technique, guided surgery using a tooth, mucosal or bone borne guide or a combination of these approaches can be a predictable method for dental implant placement.
- Although it increases the number of steps compared to freehand placement, guided implant surgery allows clinicians to develop a restoratively driven surgical plan, with the ultimate goal of patient-centered, positive outcomes.
- Surgical guides can assist the practitioner in avoiding damage to anatomic structures, as well as limiting fenestration and dehiscence of the alveolar ridge at potential implant sites.

The purpose of this study is to evaluate the accuracy of angulation of the implants placed using surgical guides by superimposing the cone beam computed tomography scan of actual implant that was placed on the patient over pre-operatively virtually planned implant position.

Aims & Objectives

AIMS AND OBJECTIVES

The aim of study is to evaluate the accuracy of dental implant positioning placed using digitally planned 3D printed surgical guide .

Review of Literature

REVIEW OF LITERATURE

David R. Burns, D.M.D., Donald G. Crabtree, D.D.S., and Dewey H. Bell, D.D.S. (1988) described a technique for fabrication of a surgical guide that gives the surgeon the appropriate location and angulation of the submerged implant relative to the opposing dentition. Presurgical planning for submerged implant location and angulation within bone relative tothe opposing occlusion was important for the restorative dentist. This information would be accurately communicated to the surgeon by using a surgical template.[1]

Igor J. Pesun, DMD and F. Michael Gardner, DDS, MA (1995) described a technique in which a guide was fabricated for radiographic evaluation of implant placement and also serves as a surgical guide for placement of the implants for a patient with severely worn dentition. They also added that it provides for visualization of the final restoration and can be modified to be used for implant placement. Chair and laboratory time were reduced because one guide could be used for both radiographic evaluation and surgery. The guide was easily fitted to the existing dentition and allows evaluation of the contours of the final restoration in the patient's mouth by the patient, the restoring dentist, and the surgeon. The use of a known diameter gutta-percha plug could determine the distortion factor of the radiographic image, if it was used for tomographic and panoramic radiographs.[2]

Naitoh M, Ariji E, Okumura S, Ohsaki C, Kurita K, Ishigami T (1999) conducted a study to propose a method for evaluating the placement accuracy using a specific surgical template. Their results showed that the template used in our procedure had a sufficient quality in identifying the proposed direction, because the difference could be recovered by the greater access hole of the set-screw (Parel & Sullivan 1989) and the use of the angulated abutment. Although this method was difficult to apply to individual cases, it may be useful to evaluate a procedure for implantation.[3]

Roger A. Sollow(2001) stated that, Radiographic surgical template related the position of the planned implant site to the remaining bone.. A surveyor - mounted handpiece was not required. Clean enlargement of the access opening was possible without shredding plastic or metal tubing. The pilot drill aligned was controlled. A surveyor was used to orient the composite channel to the ideal position or to match the emergence profile of adjacent teeth. Correction of pilot drill channel was possible after radiographic evaluation. The desired correction in angulation was measured with a protractor on the tomogram. The composite channel was enlarged, and the bur shank was rebonded with composite to this new angle by placing the protractor on the surveyor rod. Any desired horizontal change was measured with Calipers from the tomogram. This dimension was transferred to the new bur shank position in the enlarged channel, and the composite is rebonded. This technique allows control of marker orientation. The composite marker represents the central axis of the prosthetic tooth and is a better indicator of the tooth to-bone relationship than a radiopaque outline of the tooth or denture base. The access opening in the radiographic surgical template that confines the composite should be perpendicular to the occlusal plane or parallel to the adjacent teeth. The marker angulation was apparent in the vertical slices of the tomogram, could be used in fully edentulous patients by extending the acrylic resin to cover the palate, tuberosity, or retromolar pads on the duplicate diagnostic cast and retained as a guide to locate healing screws at the second stage surgery. The author summarized that versatile radiographic-surgical template for multiple parallel implant placement has been described. Simple materials and methods allow the restorative dentist to evaluate the final prosthetic contours, implant locations, and treatment plan before surgical or patient consult. The precise guide for implant pilot drills could be modified easily after radiographic evaluation or during surgery.[4]

Kıvan Aka, DDS, PhD, Haldun I plikioglu, DDS, PhD, and Murat C. ehreli, DDS, PhDc (2002) conducted a study which describes a modified surgical stent that serves as a guide to proper mesiodistal paralleling of dental implants. They concluded that when computerized tomography was not required to evaluate the buccolingual angulation of available bone, the simple design and function of the modified stent make it advantageous for use in the posterior edentulous mandible.[5]

Kevin C. Kopp, BS, DDS, Alyson H. Koslow, BS, DDS, and Omar S. Abdo, BDS, MSc (2003) presented an article about precise dental implant placement. A barium-coated template with external guide wires used in conjunction with a computed tomography scan and interactive software may provide superior presurgical diagnostics, treatment planning, and prosthetically directed implant placement. Measurements predetermined on the computed tomography scan could be transferred accurately to the diagnostic/surgical template by use of a precision milled cylinder placed into the template at the proper angulation and linear dimensions. The diagnostic/surgical template demonstrates the surgeon the optimal position for implant placement, thus establishing greater clinical confidence when placing implants. They concluded that the location of implant placement was often critical to the success or failure of a particular restoration. .Placing a wire buccally allows for the marker to remain intact and not be obliterated when preparing the template for the surgical phase. With this method, the buccolingual and mesiodistal positions could be maintained throughout the surgery. This was accomplished by affixing an external guide wire that remains with the template from diagnostic CT imaging to surgical placement of the implant.

The use of a diagnostic/surgical template may allow predictable implant placement and was simple and inexpensive to fabricate.[6]

Antonio Rocci, DDS, Massimiliano Martignoni, DDS, Jan Gottlow, DDS, PhD (2003), conducted a study to evaluate an immediate-loading treatment protocol, which included flapless surgery, implants placed in predetermined positions and connected to prefabricated provisional restorations, and the 3 year clinical results. They concluded that the feasibility of an immediate-loading treatment protocol in the maxilla, which included flapless surgery, implants and abutments placed in predetermined positions, and prefabricated provisional restorations. All failures occurred within the first 2 months of loading. The unchanged survival rate and the low average bone loss found during the following 3-4month study period indicate a good long-term prognosis for the performed immediate-loading treatment.[7]

Mohammed Zaheer Kola, Altaf H Shah, Hesham S Khalil, Ahmed Mahmoud Rabah, Nehad Mohammed H Harby, Seham Ali Sabra, Deepti Raghav (2004) mentioned that Improvements in surgical reconstructive methods, as well as increased prosthetic demands, require a highly accurate diagnosis, planning, and placement. Identification of the bony anatomy with respect to the teeth, prior to surgery, allows the clinician to place implants in areas where the implant bone interface could be maximized, and the prosthetic result was optimized. As discussed earlier, the completely limiting design was considered far superior design concept, most clinicians still adopt the partially limiting design due to its cost effectiveness and credibility in the field; in addition, it had been observed that most clinicians use surgical guide templates that are based on cross sectional imaging to facilitate accurate planning and guidance during the surgical phase. Computer aided planning and image guided surgery can be carried out, when implant positioning is to be precisely executed, and when safe positioning of implants with optimal use of available bone, and whenever a CT scan was recommended as a diagnostic means evidence based research still needs to be conducted to evaluate the applications of the completely limiting design and its effect on the treatment outcome in oral implantology.[8]

Jakob Brief, Dieter Edinger ,Stefan Hassfeld Georg Eggers (2005) conducted a study to assess accuracy of two commercially available systems for image-guided dental implant insertion based on infrared tracking cameras was compared with manual implantation. Phantoms of partially edentulous mandibles were used. In a master phantom, pilot boreholes for dental implants were placed. These boreholes were reproduced in slave phantoms using either of the two image-guided systems and manual implantation. The resulting positions were determined using a coordinate measurement machine and compared with the master model. In comparison with manual implantation, the difference of borehole positions to the master phantom was significantly lower using either of the systems for image-guided implant insertion. They concluded that the Image-guided insertion of dental implants is significantly more accurate than manual insertion. However, the accuracy that can be achieved with manual implantation is sufficient for most clinical situations.[9]

Giovanni A.P. Di Giacomo,Patricia R. Cury, Ney Soares de Araujo, Wilson R. Sendyk,and Claudio L. Sendyk (2005) concluded that computer-aided rapid prototyping of surgical guides may be useful in implant placement. However, the technique requires improvement to provide better stability of the guide during the surgery, in cases of unilateral bone-supported and non-tooth-supported guides. Further clinical studies, using greater number of patients, were necessary to evaluate the real impact of the stereolithographic surgical guide on implant therapy.[10]

Alan L rosenfeld,George A.mandelaris,philippe B.Tardieu (2006) conducted a study to discuss the use of scanning appliances to transfer clinically relevant prosthetic outcome information to a ct data set. This information could be used to provide a pretreatment outcome analysis using implant software which could be used for fabrication of models and surgical drilling guides used during osteotomy preparation. They also stated that interactive CT technology allows the incorporation of prosthetic information into a CT study which could be analysed against the patients regional anatomy before surgical intervention. Surgical requirements could be established prior to treatment. This technology allows for the process of informed consent to be conducted.[11]

Gerlig Widmann, MD/Reto Josef Bale, MD (2006) presented an article to review the different factors and limitations influencing the accuracy of computer-aided implant surgery. They mentioned that the accuracy of image-guided systems for oral implant surgery depends on all cumulative and interactive errors involved, from the data-set acquisition to the surgical procedure. A safety distance at least equivalent to the maximum deviation of the individual system was necessary. Similar accuracy data had been reported for bur tracking and image-guided template production, and both methods allow precise positioning of oral implants. Compared to the conventional technique, computer-aided implant surgery was superior on account of its potential to eliminate error and systematize reproducible treatment success. It also enables the protection of critical anatomic structures and the esthetic and functional advantages of prosthodontics - driven implant positioning.

Based on clinical data, image guidance was not required for easy cases of sufficient anatomic orientation and bone height, but whenever a CT scan is recommended as a diagnostic means, when prosthodontic-driven implant positioning was to be precisely executed, and when safe positioning of implants with maximum length was desired for optimal use of the available bone, the patient could fully benefit from the advantages of complete 3-dimensional imaging, computer aided planning, and image-guided surgery. Long term clinical studies were necessary to examine all aspects of treatment success, to confirm the value of this strategy, and to justify the additional radiation dose, effort and costs.[12]

Dov M. Almog, DMD B. W. Benson, DDS, MS L. Wolfgang, DDS N. L. Frederiksen, DDS, PhD S. L. Brooks, DDS, MS (2006) stated that report reviews recent developments in CT-image–based information and surgical guidance systems and attempts to provide an argument for the development to evidence-based research on the utility of such systems and their effect on the outcome in oral implantology. Outcomes assessment research, including cost-to-benefit analysis, difficult but was critical in answering these and other questions about implant site assessment and surgical guidance. Furthermore, the recent introduction of numerous associated commercial CT-based imaging and surgical guidance platforms and its expected effects on the way the profession views and practices oral implantology provides sufficient argument for the necessity of large prospective clinical trials on the quantitative relationship between successful dental implant treatment outcomes and CT-based dental imaging coupled with surgical guidance systems.[13]

Kunal Lal, DDS, MS, George S. White, DDS Dennis N. Morea, DDS and Robert F.Wright, DDS (2006) presented an article about the use of Stereolithographic templates for Surgical and Prosthodontic Implant Planning and Placement. They concluded that the stereolithographic templates could be used in completely as well as partially edentulous situations. The templates could be entirely supported either by soft tissue,bone,or remaining teeth. The cost associated was higher than with conventional templates, but in more complexes, fully edentulous cases, the benefit could justify the additional expense. The use of this approach could make the goal of ideal surgical and prosthodontic implant placement a distinct possibility. Considering the possible benefits and implications of achieving this goal, it would be prudent to direct further clinical research endeavors toward validating the accuracy and effectiveness of the system.[14]

Van Assche N, van Steenberghe D, Guerrero ME, Hirsch E, Schutyser F, Quirynen M, Jacobs R (2007) conducted a study to evaluate the precision of transfer of a Computer - based three-dimensional (3D) planning, using re-formatted cone-beam images, for oral implant placement in partially edentulous jaw. In his study four formalin-fixed cadaver jaws were imaged in a 3D Accuitomo FPDs cone-beam computed tomography (CT). Data were used to produce an accurate implant planning with a transfer to surgery by means of stereolithographic drill guides. Pre-operative cone-beam CT images were subsequently matched with post-operative ones to calculate the deviation between planned and installed implants. The surgical procedure was performed uneventfully. Finally they stated that the ability of cone-beam CT images to offer a reliability data set for planning and further transfer of oral implant placement in partial edentulism. The study also indicates that the results could be improved by considering the various crucial points such as template fit and template stability and concluded that cone-beam images could be used for implant planning, taking into account a maximal 4 degree angular and 2.4mm linear deviation at the apical tip.[15]

Loong Tee Yong, BDS, MD, FRACDS;Peter K. Moy, DMD (2007) conducted a study to evaluate early clinical results of computer-aided design (CAD)/computer-aided machining (CAM)-guided surgical implant placement (NobelGuide™, Nobel Biocare,Yorba Linda, CA, USA) with focus on surgical and/or prosthetic complications, management, and prevention. Thirteen patients rehabilitated between March 2003 and October 2006 with CAD/CAM-guided dental implants and immediate loading were evaluated. The treatment planning and procedures were carried out in accordance to the system protocol. The complications encountered in this case series were classified and assessed according to early (planning and procedural – surgical; prosthetic) and late complications (surgical; prosthetic). They finally stated that the prosthetic complications Out numbered surgical complications both in the early and late treatment phases and the Nobel Guide system is a reliable treatment modality but not without its complications.[16]

Natalie Y. Wong, DDS, Heather Huffer-Charchut, DMD, and David P. Sarment, DDS, MS (2007) stated that new technological advances in CAD/CAM implant treatment planning and guidance may offer significant clinical advantages over traditional implant rehabilitation. In this report, the use of a soft-tissue supported CAD/CAM guide was suggested as a method to transfer the CT-based implant plan to actual surgery.A detailed, comprehensive approach to complex implant treatment planning and surgical implant placement offers advantages to both clinician and patient.[17]

Philippe B. Tardieu, DDS/Luc Vrielinck, DMD/Eric Escolano, DMD(2007) presented a case of immediate loading of mandibular implants using a 5-step procedure. The first step progress in medical imaging and data processing was creating profound changes in the way that professional practice was perceived. Treatments are becoming more precise, faster, and safer for patients. Surgeons were now well equipped in controlling and carry them out with precision of implant positioning also helps in reducing the cost of prosthetic restorations, avoiding the use of additional abutments to realign implants. Implant treatment with immediate loading using a bone-supported stereolithographic drill guide has been demonstrated in this treatment situation. Implant treatment with immediate loading using a bone-supported stereolithographic drill guide has been demonstrated in this treatment situation. This drill guide may be called the “missing link” in implant treatment.[18]

O. Ozan, I. Turkyilmaz & B. Yilmaz (2007) presented a clinical study to compare the survival rates of early loaded implants placed using flapless and flapped surgical techniques and to determine the bone density in the implant recipient sites using computerized tomography (CT). The study population consisted of 12 patients who were referred implant placement. One group consisted of five patients referred for the placement of 14 implants and treated with a flapless procedure. The other group consisted of seven patients referred for the placement of 45 implants with a conventional flapped procedure. Patients were selected randomly. CT machine was used for pre-operative evaluation of the jaw bone and the mean bone density value of each implant recipient site was recorded in Hounsfield units (HU). All implants were placed using CT guided surgical stents. The early loading protocols included 2 months of healing in the mandible and 3 months of healing in the maxilla. Single-implant crowns, implant-supported fixed partial dentures, and implant-retained over dentures were delivered to the patients. The results of this study show that the early loading of implants placed utilizing flapless surgical technique with CT-guided surgical stents may be possible.[19]

Hans Joachim NICKENIG, Stephen EITNER (2007), presented a study to assess the reliability of planning software system that allows transfer of virtual planning data to a surgical template that is then used as a drill guide during surgery. They finally mentioned that implant placement after virtual planning of implant positions using CBCT data and surgical templates could be reliable for pre-operative assessment of implant size, position and anatomical complications. It is also indicative of cases amenable to flapless surgery.[20]

Ai Komiyama, Bjorn Klinge, Margareta Hultin(2008) presented an article to evaluate the outcome of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning combined with flapless surgery.They concluded that the patient’s post-operative discomfort, such as pain and swelling was almost negligible in successfully treated cases. However, compared with conventional treatment protocols and the Branemark Novums, the occurrence of surgical and technical complications was higher in edentulous mandibles. Thus, the method of computer-assisted treatment planning and immediate loading must still be regarded to be in an exploratory phase. Further investigations were needed to validate the accuracy in the method taking into account each step in the clinical procedure. The positioning of implants after guided surgery and 3D virtual planning still had to be verified in both maxilla and mandible. Continued investigations along these lines were in progress in both our clinics and laboratories.[21]

Leonard Spector (2008) mentioned that technologic advances in computer based planning of implants as allowed the clinician to plan more accurately and place dental implants precisely. With the planning software, the virtual treatment plan was used to create a surgical template that guides the placement of implants during surgery. The minimally invasive surgery was performed without raising the flap, thereby minimizing surgery time, post-operative pain and swelling and recovery time. The guided implant surgery was very helpful to plan, place and restore implants accurately with the level of precision.[22]

David Schneider, Ronald E. Jung (2009), conducted a study to analyse the dental literature regarding accuracy and clinical application in computer-guided template-based implant dentistry. For this, an electronic literature search complemented by manual searching was performed to gather data on accuracy and surgical, biological and prosthetic complications in connection with computer-guided implant treatment. For the assessment of accuracy meta-regression analysis was performed. Complication rates are descriptively summarized. They concluded that, Computer-guided template-based implant placement showed high implant survival rates ranging from 91% to 100%. However, a considerable number of technique related perioperative complications were observed. Preclinical and clinical studies indicated a reasonable mean accuracy with relatively high maximum deviations. Future research should be directed to increase the number of clinical studies with longer observation periods and to improve the systems in terms of perioperative handling, accuracy and prosthetic complications.[23]

U. S. Pal, Pooran Chand, Neeraj Kumar Dhiman, R. K. Singh, Vimlesh Kumar (2010) demonstrated the extreme accuracy of the conventional surgical stent. If each step of this protocol was followed precisely, it was possible to deliver an optimum implant installation in terms of position and diameter and later on function at a very much reduced rate and time, as taken in CT and CAD/CAM technology which are the most accepted methods.[24]

Christoph Vasak, Georg Watzak, Andre ´ Gahleitner, Georg Strbac, Werner Zechner (2010) conducted a retrospective study to evaluate the overall deviation in a clinical treatment setting to provide for quantification of the potential impairment of treatment safety and reliability with computer-assisted, template-guided transgingival implantation. The patient population enrolled (male/female¼10/8) presented with partially dentate and edentulous maxillae and mandibles. Overall, 86 implants were placed by two experienced dental surgeons strictly following the NobelGuide protocol for template-guided implantation. All patients had a postoperative computed tomography (CT) with identical settings to the preoperative examination. Using the triple scan technique, pre- and postoperative CT data were merged in the Procera planning software, a newly developed procedure – initially presented in 2007 allowing measurement of the deviations at implant shoulder and apex. They concluded that template-guided implantation will ensure reliable transfer of preoperative computer assisted planning into surgical practice. With regard to the required verification of treatment reliability of an implantation system with flapless access, all maximum deviations measured in this clinical study were within the safety margins recommended by the planning software.[25]

Curtis M. Becker, DDS, MSD, and David A. Kaiser, DDS, MSD (2010) conducted a study for describing a procedure for constructing a precise surgical guide that ensures appropriate placement of dental implants. If implants were placed properly, the position of abutments would be suitable.

This would result in a functional and esthetically pleasing restoration. Although the procedure is time-consuming during the diagnostic phase of treatment, it is worth the effort to ensure a long-term esthetic and functional result.[26]

Volkan Arısan, Z. Cuneyt Karabuda, and Tayfun O zdemir (2010) conducted a study in which accuracy of two stereolithographic surgical guide systems by support type (i.e., bone, tooth, and mucosa) was analyzed and compared. After enrolling 54 eligible patients, 294 implants were planned on cone-beam computerized tomography CBCT-derived images.

Sixty guides, both single- and multiple-type, were produced using two commercial systems.

Mucosa-supported guides were fixed with osteosynthesis screws. Implants were inserted, and at the end of osseointegration period, a new CBCT scan was performed. Preoperative planning was merged with the new CBCT data to identify the deviations between the planned and placed implants for each support type and manufacturer. The Kruskal-Wallis and

Mann-Whitney U tests were used for comparison ($P < 0.05$). There were no damage-related complications in any critical anatomy. Implants that were placed by bone supported guides had the highest mean deviations (5.0– 1.66angular, and 1.70 – 0.52 mm and 1.99 – 0.64 mm for implant shoulder and tip, respectively), whereas the lowest deviations were measured in implants that were placed by mucosa-supported guides (2.9–0.39 angular, and 0.7 – 0.13 mm and 0.76–0.15 mm for implant shoulder and tip, respectively). They concluded that Computer-aided planning and manufacturing surgical guides in accordance with CBCT images may help clinicians place implants. Rigid screw fixation of a single guide incorporating metal sleeves and a special drill kit further minimizes deviations.[27]

Manikandan Ramasamy, Giri, Ramesh Raja, Subramonian, Karthik, Rachuri Narendrakumar (2013) stated that to achieve a successful final treatment outcome, a position at least equivalent to the maximum deviation of the implant placement was necessary. This had been best achieved clinically with the help of a computer aided surgical guide. But compared to the conventional technique, limitation with computer aided implant surgery requires substantially greater investment and effort. Based on clinical data, image guidance is not required for cases with sufficient anatomic orientation and bone height. Computer aided planning and image guided surgery could be carried out, when implant positioning was to be precisely executed, and when safe positioning of implants with optimal use of available bone, and whenever a CT scan is recommended as a diagnostic means.[28]

Bruno Ramos Chrcanovic, Tomas Albrektsson,, Ann Wennerberg (2014) conducted a study to test the null hypothesis of no difference in the implant failure rates, postoperative infection, and marginal bone loss for patients being rehabilitated by dental implants being inserted by a flapless surgical procedure versus the open flap technique, against the alternative hypothesis of a difference. They concluded that the difference between the procedures (flapless vs. flapped) statistically affected the implant failure rates. However, the results must be interpreted carefully, as a sensitivity analysis revealed differences when the groups of studies of high and low risk of bias were pooled separately. No statistically significant effects of open flap surgery or flapless surgery on the occurrence of postoperative infection and on the marginal bone loss were observed.[29]

Maria Romero-Ruiz, Regina Mosquera-Perez, Jose-Luis Gutierrez-Perez, Daniel Torres-Lagares (2015) mentioned that flapless technology in implantology allows to make intervention with a minimum aggression to both the bone and soft tissues, shortening the surgery time and achieving high levels of satisfaction by the patient. Patients treated with anticoagulant drugs or medically compromised equally can get benefitted by this minimal invasion technique. They also stated that the main obstacle of flapless surgery was the fact of limited visibility of the drilling and during implant placement, so the risk of causing wrong bone directions or damaging neighbour structures is higher than with the conventional technique.[30]

Scott ganz (2015) summarizes that technology continues to improve, and imaging modalities become widely available, clinicians worldwide were increasingly adopting guided surgical applications for dental implants. Although CT/CBCT diagnosis and treatment planning were still not universally taught in dental schools at either the undergraduate or postgraduate levels, clinicians were becoming more aware of the benefits of proper planning through advanced imaging modalities and interactive treatment planning applications. It should be emphasized that all aspects of the planning phase were based on sound surgical and restorative fundamentals. However, it must also be stated that “It’s not the Scan, it’s the PLAN,” meaning that guided surgery applications are dependent on careful diagnosis using the advanced tools that 3-dimensional imaging offers in combination with advanced interactive treatment planning software. Yet this alone is not sufficient. Clinicians who wish to achieve true restoratively driven implant dentistry must be aware that the diagnostic phase often begins before the scan is taken. The use of diagnostic wax-ups, radiopaque scanning appliances, and the incorporation of intraoral optical scanners could significantly enhance the process and improve accuracy. Perhaps the most exciting aspect about the new digital workflow was the ability to take the information from the diagnostic wax-up as confirmed by the 3-dimensional planning and combine this with CAD CAM software to design first a transitional restoration and then the final restoration.[31]

Marjolein Vercruyssen, Isabelle Laleman Reinhilde, Jacobs Marc Quirynen (2015) conducted a study to give an overview of the workflow from examination to planning and execution, including possible errors and pitfalls, in order to justify the indications for guided surgery using pubmed data base. The transfer of the implant planning (in a software program) to the operative field remains however the most difficult part. Guided implant surgery clearly reduces the inaccuracy, defined as the deviation between the planned and the final position of implant in the mouth. It might be recommended for the following clinical indications: need for minimal invasive surgery, optimization of implant planning and positioning (i.e. aesthetic cases), and immediate restoration was his result and concluded that the digital technology rapidly evolves and new developments have resulted in further improvement of the accuracy. Future developments include the reduction of the number of steps needed from the preoperative examination of the patient to the actual execution of the guided surgery. The latter will become easier with the implementation of optical scans and 3D printing.[32]

Rosen borisov (2016) mentioned about literary sources concerning the use of radiological templates and surgical guides were reviewed in the dental implant treatment. On comparable bases, modern digital concepts have been explored in their preparation. The advantages and problems associated with their use have been analysed in his study.[33]

Boyoung Ma, Taeseok Park, Inkon Chun, Kwidug Yun (2018) conducted a study to assess the accuracy of the implants placed using a universal digital surgical guide. Among 17 patients, 28 posterior implants were included in this study. The digital image of the soft tissue acquired from cast scan and hard tissue from CBCT have been superimposed and planned the location, length, diameter of the implant fixture. Then digital surgical guides were created using 3D printer. Each of angle deviations, coronal, apical, depth deviations of planned and actually placed implants were calculated using CBCT scans and casts. They finally stated that the deviation obtained by the plaster cast is significantly smaller, which could be useful in evaluation of implant placement accuracy and concluded that this study showed significantly smaller deviation values using cast model analysis than those measured using the CBCT superimposition method. The angle and length deviation value of the universal digital guide stent were clinically acceptable.[34]

Materials and Methods

MATERIALS AND METHODS

Source of Data:

The study was conducted in the department of Oral and Maxillofacial Surgery, Ragas Dental college, Chennai, Tamilnadu. 15 implant sites in 4 patients irrespective of gender (two males and two females) were selected based on the inclusion criteria. These patients, who presented to the department of Oral and maxillofacial surgery Ragas Dental College and hospital with a complaint of partial or complete edentulism with a need of fixed prosthesis, were included in the study.

INCLUSION CRITERIA:

- Partially edentulous alveolar ridge.
- Completely edentulous alveolar ridge.
- Maxilla and mandible with D1, D2, D3 or D4 bone.
- Age group- 18 to 70 years.
- Both sexes.
- Patient with good oral hygiene.
- Patient who is willing for further follow up.

EXCLUSION CRITERIA:

- Bruxism.
- Smoking.
- Patients on I.V, Bisphosphonates.
- Patients taking Corticosteroids.
- Uncontrolled diabetes mellitus.
- Patients with psychiatric illness.

DESIGN OF STUDY:

PROSPECTIVE Study.

Study of 15 implants in clinical series of 4 patients.

METHODS OF COLLECTION OF DATA:

- Ethical approval was obtained from the Institutional Review Board of Ragas dental college, Chennai, Tamilnadu.
- Prospective study was done in 4 patients who required implant supported prosthesis for single tooth/ partial/ complete edentulism.
- Patients were systemically evaluated and clinically examined.
- The planned procedure was explained to patients in detail. Patients were followed up for a period of 6 months.

CASE PROFORMA AND INFORMED CONSENT FORM: A standard case sheet was used to record data on each subject during the course of the study. Information about the study was provided to all patients in a language understandable to them both orally and in writing. Informed consent was given by the subject in writing before the start of the study.

ARMAMENTARIUM:

- 2% lignocaine with 1:80,000 Epinephrine. (Fig 1)
- 27 gauge, 40 x 35 mm disposable needle. (Fig 2)
- No.15 Bard Parker Blade. (Fig 3)
- Bard Parker Handle No.3. (Fig 4)
- Molt no 9 periosteal elevator. (Fig 5)
- Surgical guiding stent. (Fig 6)
- Tissue biopsy punch. (Fig 7,8)
- Cylindrical drill sleeves. (Fig 9)
- Anchoring pins. (Fig 10)
- Physiodispenser motor and contra-angled hand piece. (Fig 11)
- Surgical screw drivers. (Fig 12)
- Surgical Implant kit which belongs to ADIN DENTAL IMPLANT SYSTEM. (Fig 13)
- 3.0 silk suture.(Fig 14)
- Pressure moulding machine vacuum plast .(Fig 15)

All these patients underwent routine blood investigations followed by complete medical evaluation.

PREOPERATIVE IMPLANT PLANNING:

For partially edentulous patient

Diagnostic impressions were made with alginate and diagnostic models were poured by orthokal. Wax up of teeth was done in the region of missing teeth of diagnostic models. Duplicate models prepared. Thermoplast sheet of 2mm thickness placed in the model through pressure moulding machine. Radiographic markers were placed on the upper part of the splint where wax up done (Fig 16). Then splint was placed in patient’s mouth and CBCT was taken by carestream scanner(resolution upto 90 µm and volume sizes from 17cm*13.5cm to 5cm*5cm,Atlanta,GA). A virtual planning was obtained through blue sky bio software(version 4.3,USA) and surgical guide was prepared. Guides were fabricated through stratasys eden 260vs computer 3D printer by polyjet printing technology.SS316 cylindrical drill sleeves were fabricated in different diameters.

For completely dentulous patient

Complete dentures were fabricated. Teeth were drilled and gutta percha sticks were inserted into the teeth. CBCT scan of the patient was taken with complete denture in patients mouth (Fig 17) .Virtual planning was performed through blue sky bio software and surgical guide was prepared. Guides were fabricated through Stratasys Eden 260vs computer 3D printer by polyjet printing technology. SS316 cylindrical drill sleeves were prepared.

INTRA OPERATIVE SURGICAL IMPLANT PLACEMENT:

Under local anaesthesia (2% lignocaine with adrenaline) implant sites were marked with a probe by placing surgical guides. Mucosal tissues were removed by tissue biopsy punch. Surgical guides were placed on the teeth. Drilling was done by placing the surgical guides through the information gained from virtual planning. Depth control system was used. A drill was inserted in the drill sleeve of master sleeve upto the physical stop of drill shaft and the next size sleeve was placed where the drill was completely inserted in to the master sleeve for achieving the implant depth. This was done in a sequential order and the final drill was placed directly in to the master sleeve. The same procedure was followed for completely edentulous patients whereas additionally anchoring pins were used to stabilise the surgical guides .The implants were placed according to the above mentioned protocol and cover screws were placed.

POST-OPERATIVE EVALUATION OF IMPLANT PLACEMENT:

After six months, postoperative CBCT were taken. A Virtual planning performed in a preoperative CBCT and post op CBCT were converted into virtual 3D models using DICOM to Print (D2P) software. These 3D models were superimposed using Geomagic Freedom software and accuracy of the angulation of the implant had been evaluated.

POST-SURGICAL PROTOCOL:

All patients were administered with a single dose of analgesic (Inj. diclofenac 75mg) intramuscularly immediately after the procedure. They were prescribed with a following regimen of oral antibiotics Cap.Amoxicillin 500mg TDS, Tab.Metronidazole 400mg TDS, analgesics Tab.paracetomol 650mg TDS and antacid Tab. Ranitidine hydrochloride 150mg BD before food for a period of 5 days.

Regular oral hygiene maintenance was advised.

SECOND STAGE SURGERY:

- Implants were uncovered (3months in case of mandible and 6 months in case of maxilla).
- Cover screws were removed.
- Healing abutments were placed for 1 week.
- Further prosthetic procedures were undertaken.

IMPLANT SYSTEM:

The implant system used in the study was Adin dental implant system(Israel). The sizes of the implants were selected according to data collected from virtual planning. (Fig. 13)

PROFORMA

NAME : AGE:

SEX :

MOB NUMBER : OP.NO:

FATHER/GUARDIAN NAME :

POSTAL ADDRESS :

OCCUPATION :

CHIEF COMPLAINT :

HISTORY OF PRESENTING ILLNESS :

PAST MEDICAL HISTORY :

PAST SURGICAL HISTORY :

PAST DENTAL HISTORY :

PERSONAL HISTROY

HABITS :

DRUGS :

BRUSHING :

GENERAL EXAMINATION

HEIGHT :

WEIGHT :

BLOOD PRESSURE :

ANAEMIA :

PULE RATE :

CYANOSIS :

CLUBBING :

LOCAL EXAMINATION

EXTRAORAL EXAMINATION

FACIAL ASYMMETRY:

TMJ MOVEMENTS :

MOUTH OPENING :

PALPATION

INTRA ORAL EXAMINATION

SOFT TISSUE :

ORAL HYGIENE STATUS:

GINGIVA:

FRENAL ATTACHMENT

UPPER :

LOWER:

TONGUE SIZE :

HARD TISSUE

TEETH PRESENT

D-

M-

F-

INVESTIGATION

STUDY CASTS:

CBCT :

CLINICAL PHOTOGRAPHS :

DIAGNOSIS:

TREATMENT PLAN:

Figures

ARMAMENTARIUM

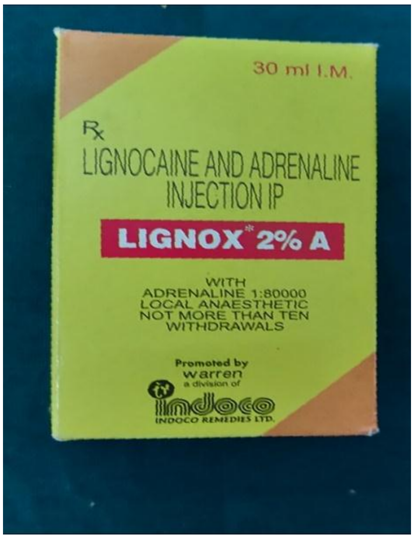


Fig 1 2%LIGNOCAINE WITH 1:80000 EPINEPHRINE.

Fig 2 27 GAUGE, 40 X 35 MM DISPOSABLE NEEDLE.

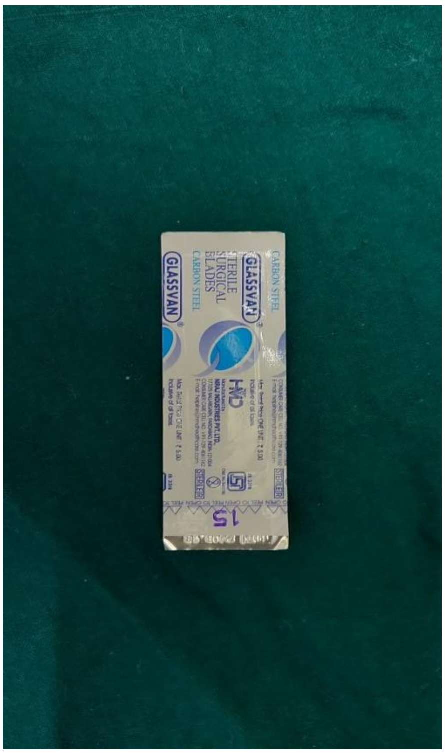


Fig 3 NO.15 BARD PARKER BLADE.

Fig 4 BARD PARKER HANDLE NO.3.

Fig 5 MOLT NO9 PERIOSTEAL ELEVATOR.

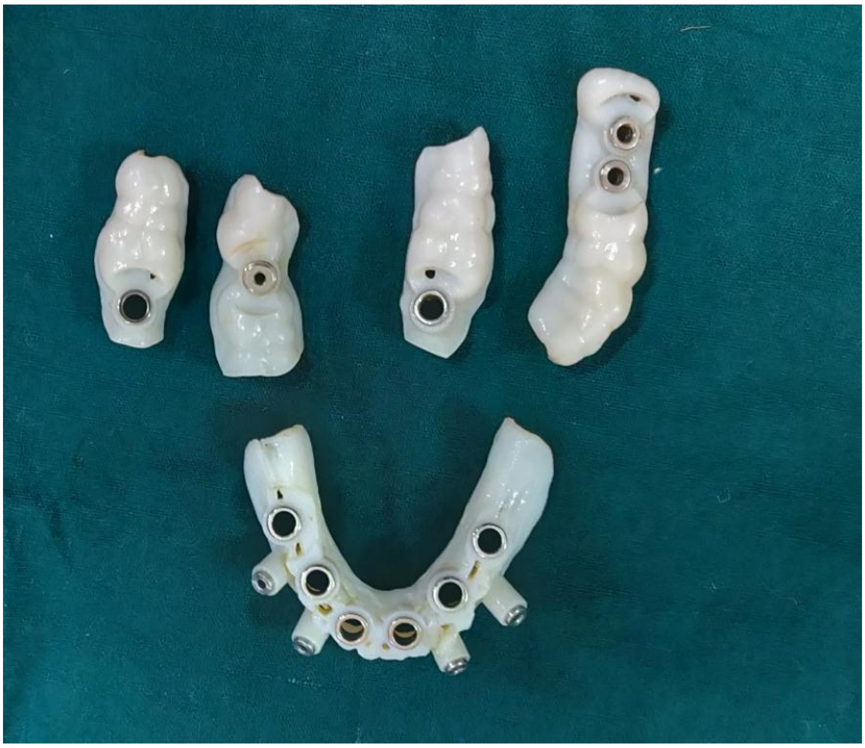


Fig 6 DIGITALLY PLANNED 3D PRINTED SURGICAL STENT.

Fig 7 TISSUE BIOPSY PUNCH (MOTOR DRIVEN).

Fig 8 TISSUE BIOPSY PUNCH(MANUAL).

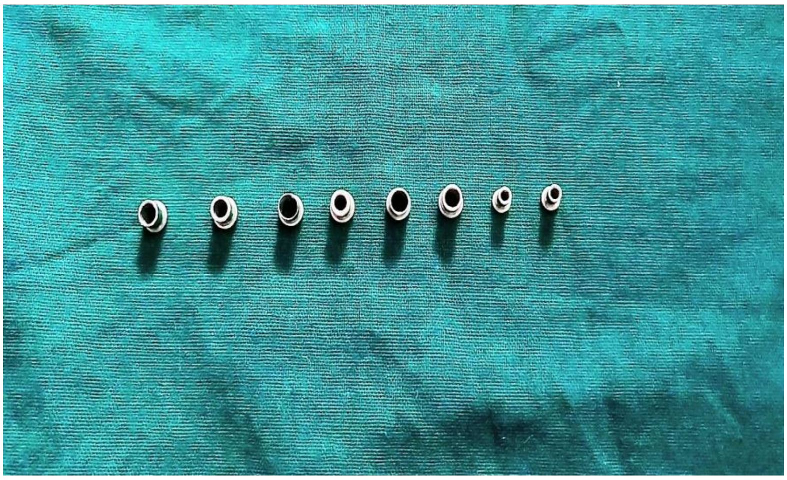


FIG 9 CYLINDRICAL DRILL SLEEVES.

Fig 10 ANCHORING PINS.

Fig 11 PHYSIODISPENSER MOTOR AND CONTRA-ANGLED HAND PIECE.

Fig 12 SURGICAL SCREW DRIVERS.

Fig 13 SURGICAL IMPLANT KIT

ADIN DENTAL IMPLANT SYSTEM.

Fig 14 3.0 SILK SUTURE.

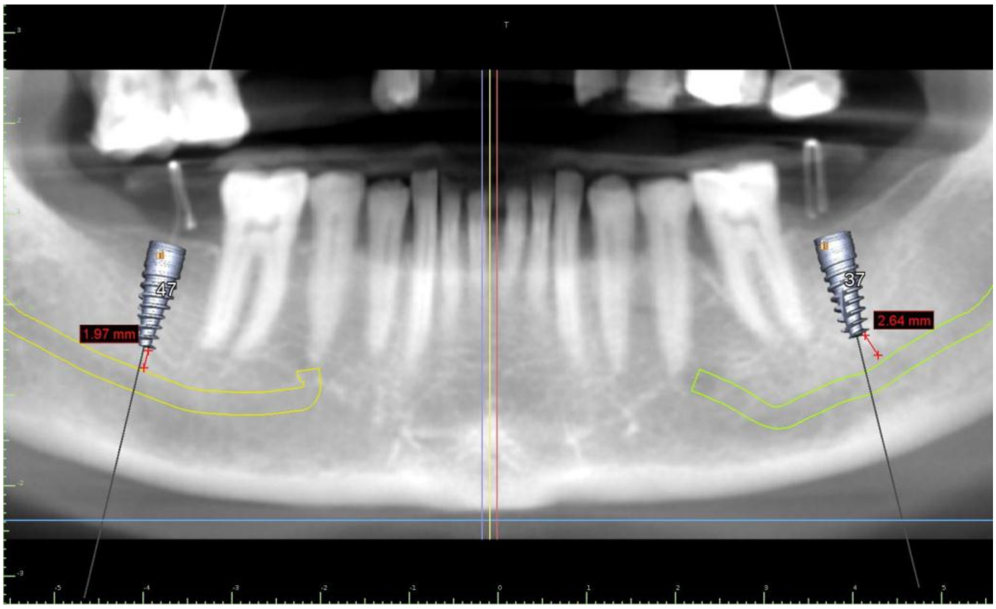
Fig 15 PRESSURE MOULDING MACHINE VACUUM PLAST.

FIG 16 RADIOGRAPHIC MARKERS PLACED ON THE UPPER PART OF THE SPLINT.

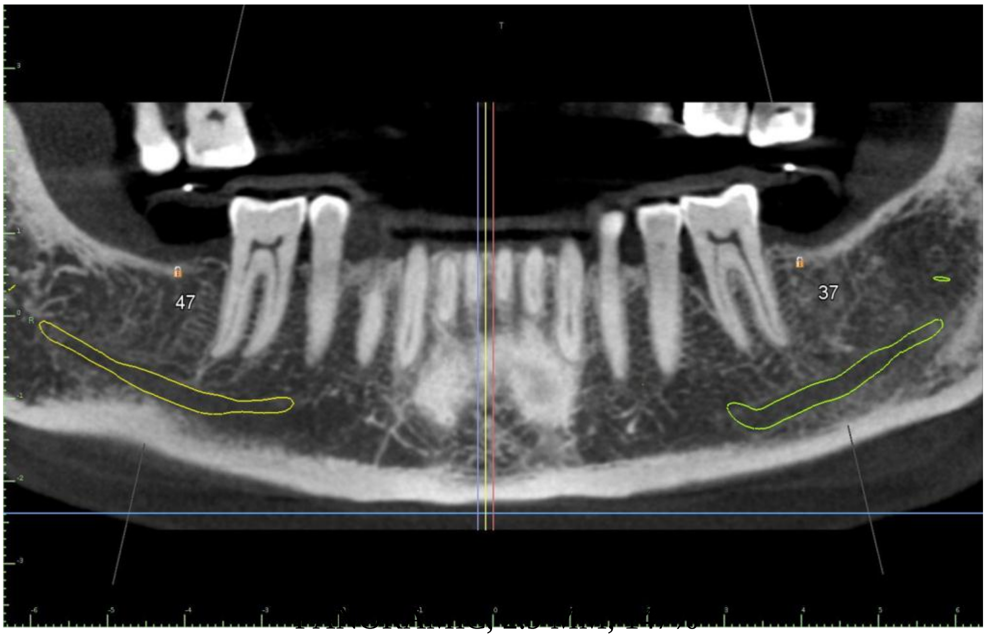
Fig 17 GUTTA PERCHA STICKS INSERTED IN TO THE ACRYLIC TEETH OF THE COMPLETE DENTURE.

CASE 1

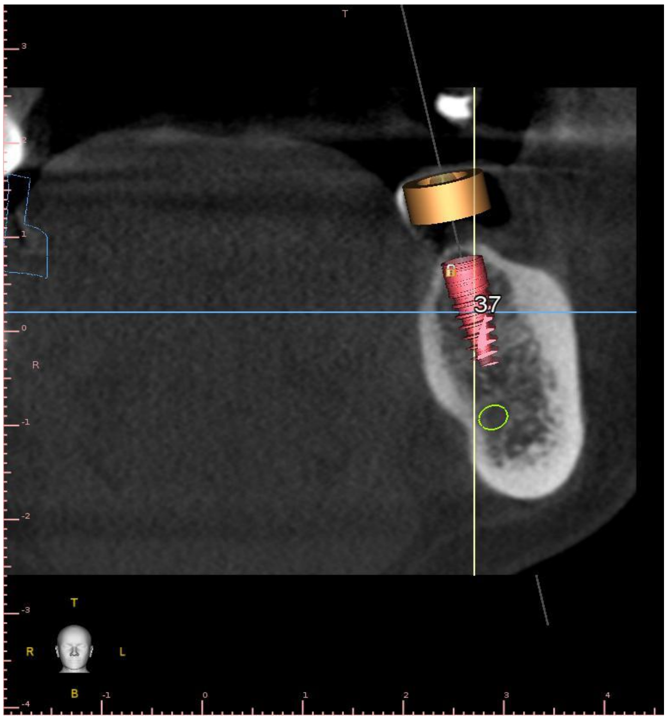
VIRTUAL PLANNING OF IMPLANTS IN THE REGION OF 37 AND 47(PANORAMIC VIEW).



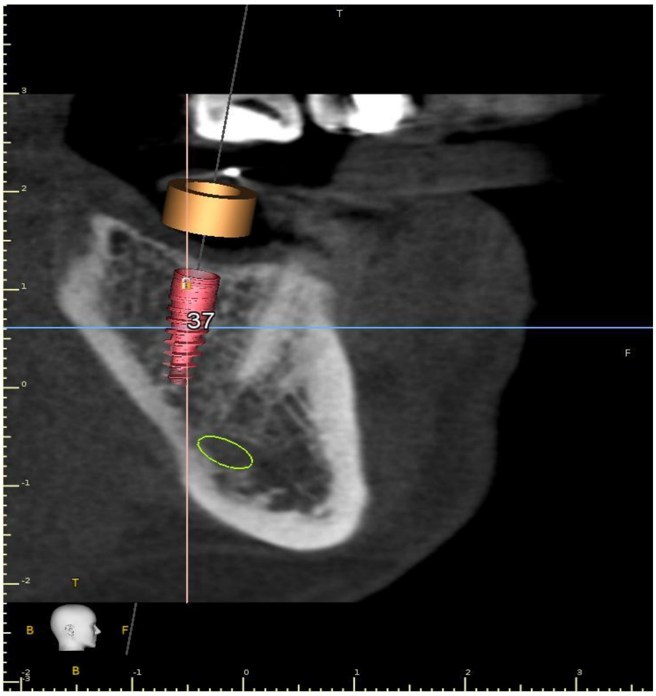
VIRTUAL PLANNING OF IMPLANTS IN THE REGION OF 37 AND 47(PANORAMIC VIEW).



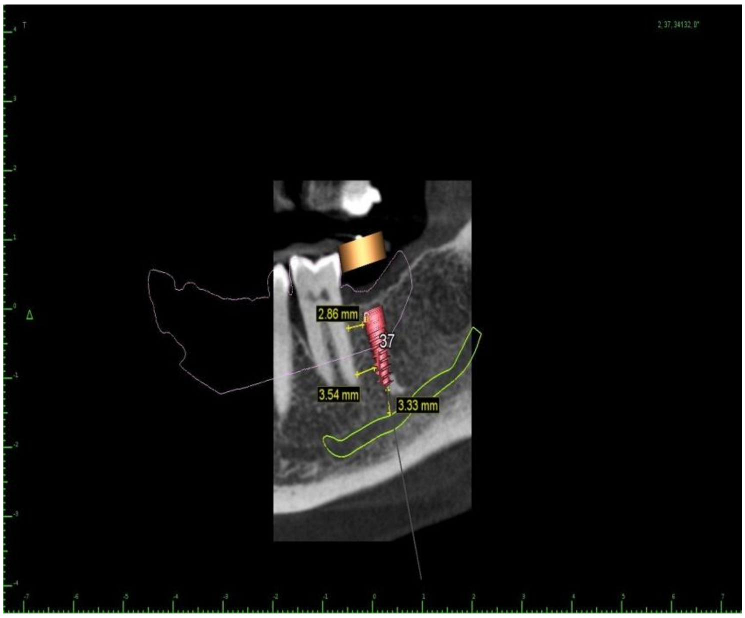
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 37(CORONAL VIEW).



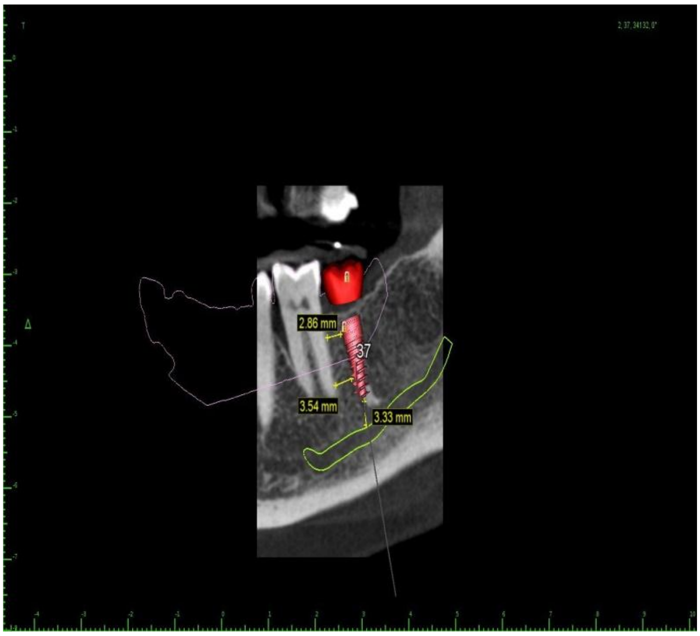
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 37 (SAGITTAL VIEW).



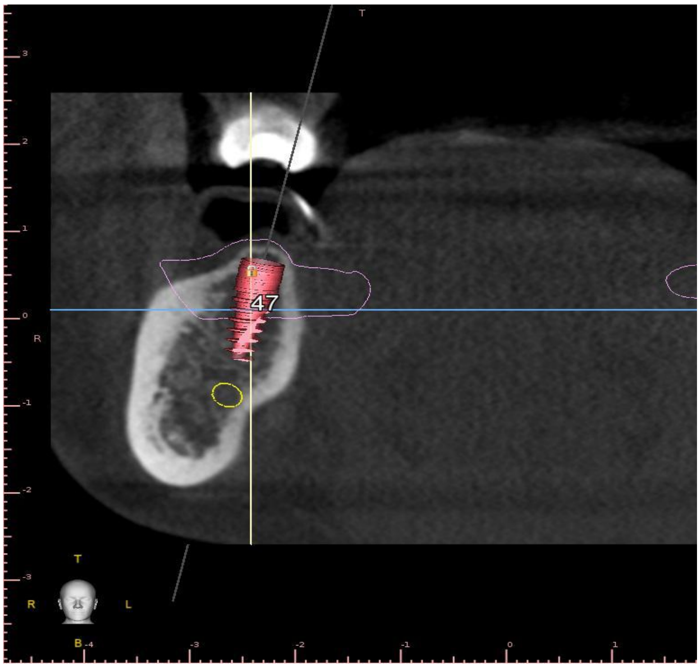
VIRTUAL PLANNING OF THE DISTANCE BETWEEN IMPLANT IN THE REGION OF 37 AND ANATOMICAL STRUCTURES.



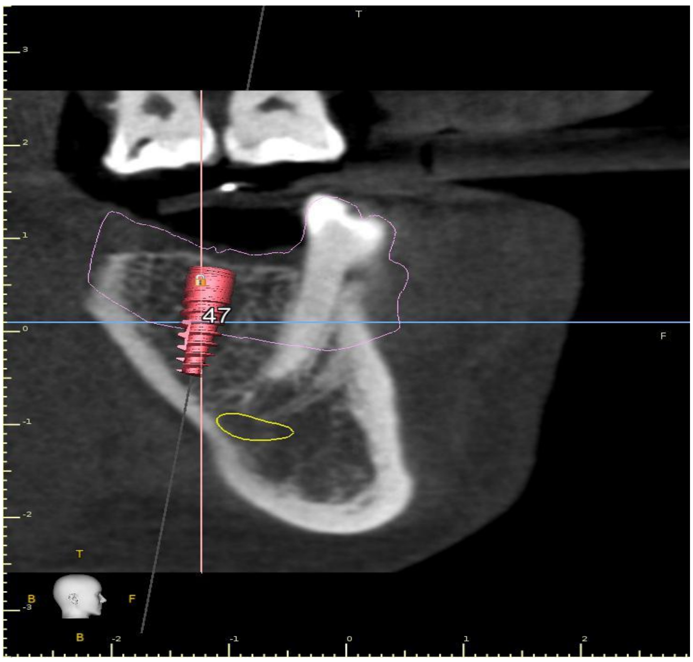
VIRTUAL PLANNING OF THE DISTANCE BETWEEN IMPLANT IN THE REGION OF 37 AND ANATOMICAL STRUCTURES.



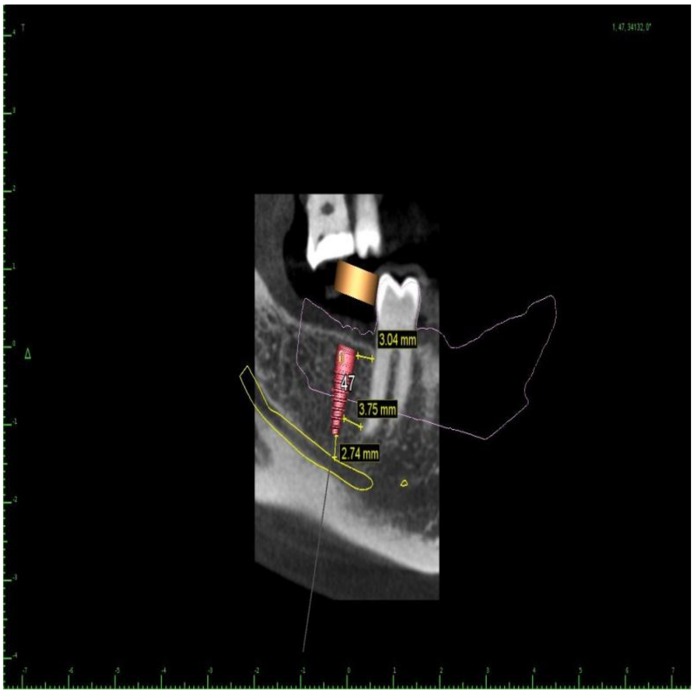
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 47(CORONAL VIEW).



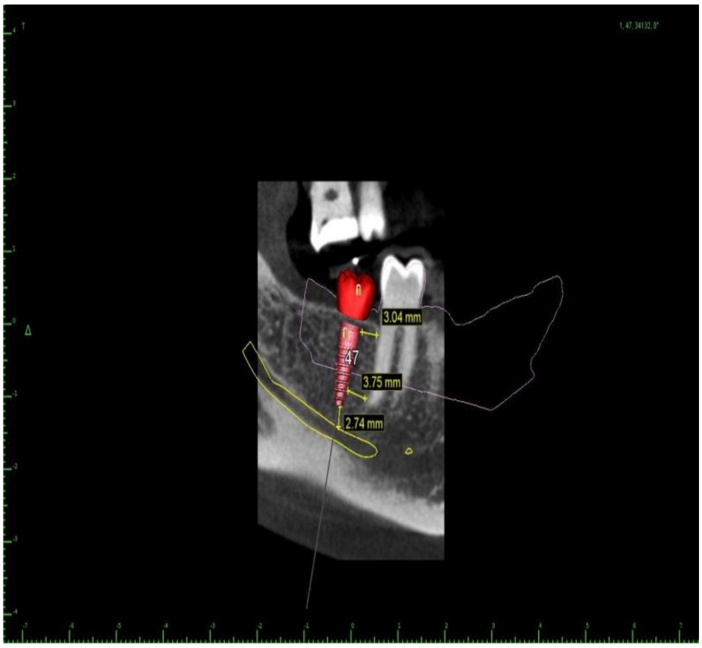
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 47(SAGITTAL VIEW).



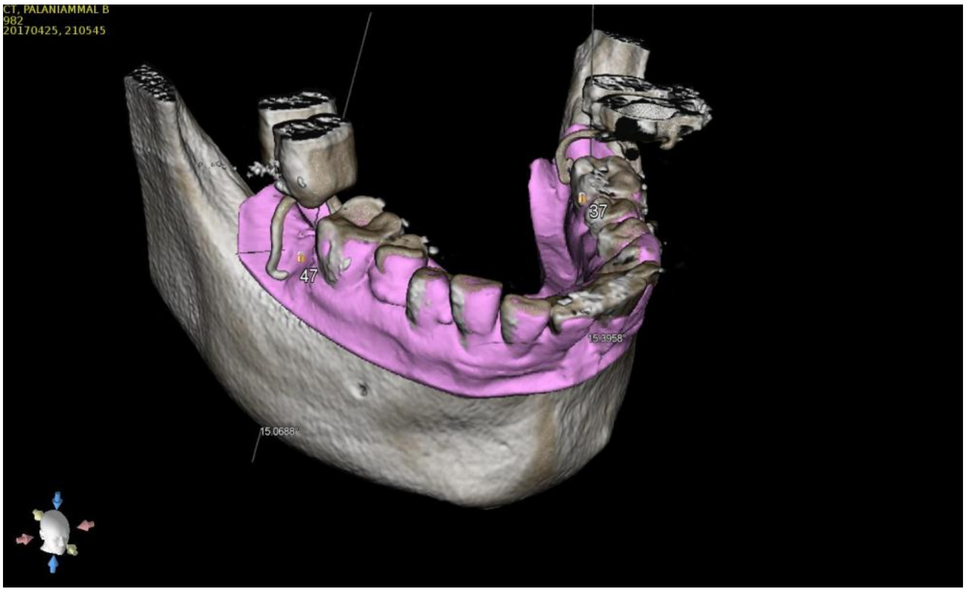
VIRTUAL PLANNING OF THE DISTANCE BETWEEN IMPLANT IN THE REGION OF 47 AND ANATOMICAL STRUCTURES.



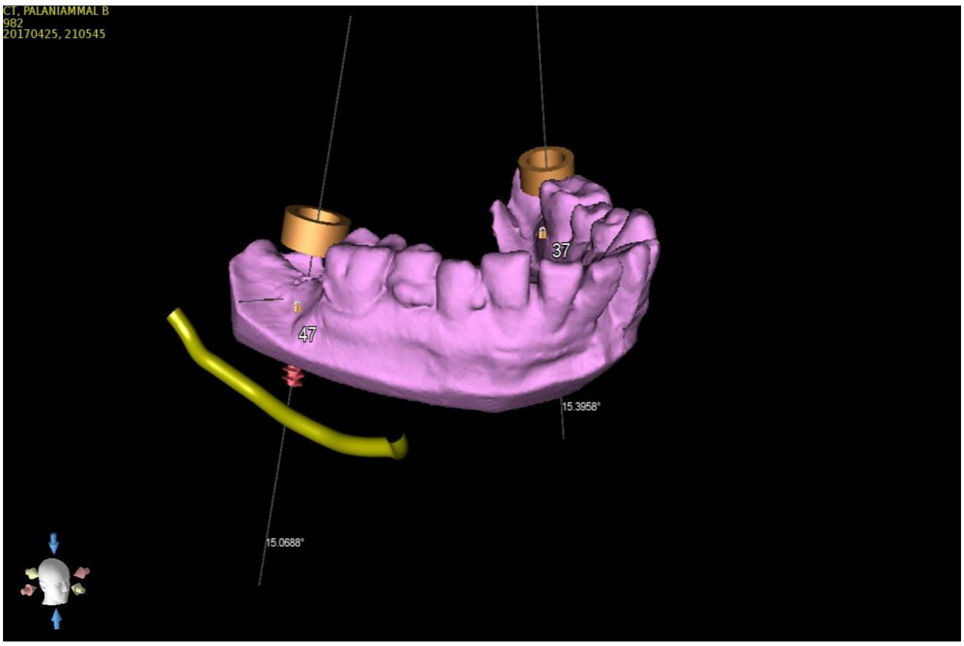
VIRTUAL PLANNING OF THE DISTANCE BETWEEN IMPLANT IN THE REGION OF 47 AND ANATOMICAL STRUCTURES.



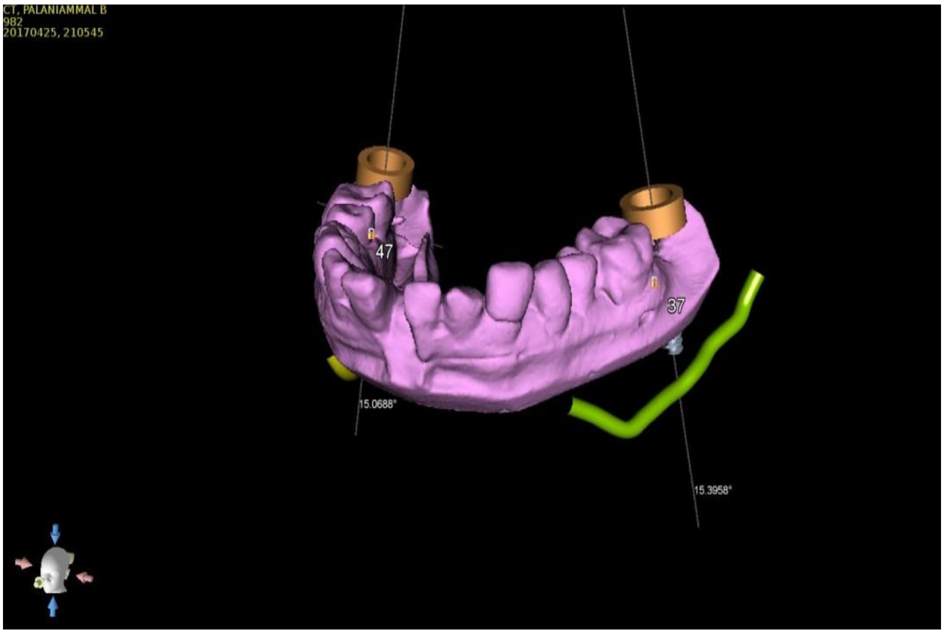
GUTTA PERCHA MARKERS PLACED IN THE REGION OF 37 AND 47(3D RECONSTRUCTION VIEW).



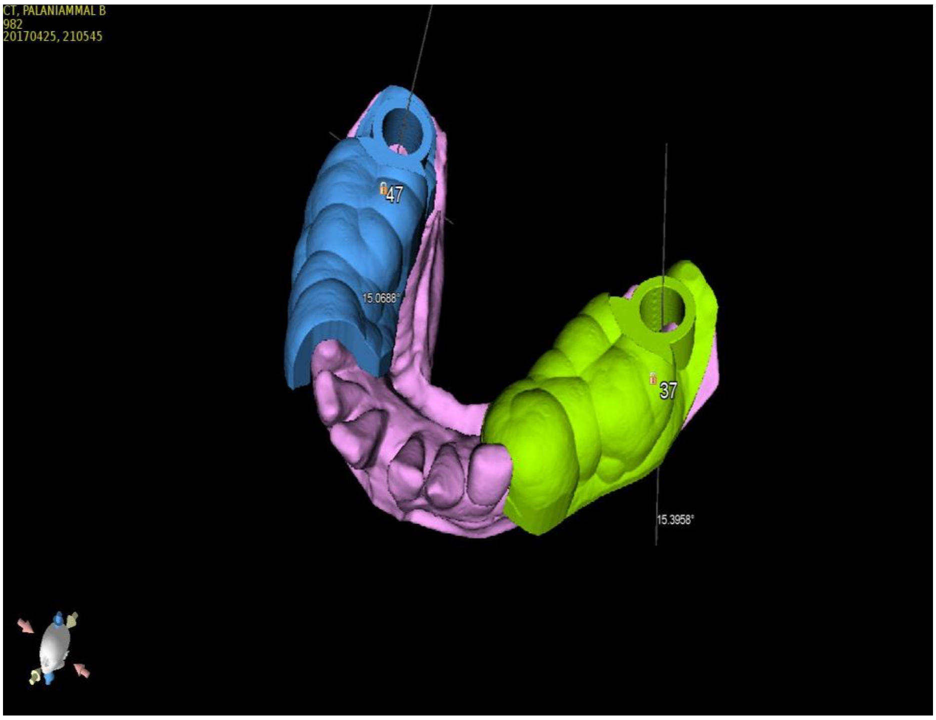
VIRTUAL IMPLANT PLANNING IN THE REGION OF 47 IN RELATION TO INFERIOR ALVEOLAR NERVE (3D RECONSTRUCTION VIEW).



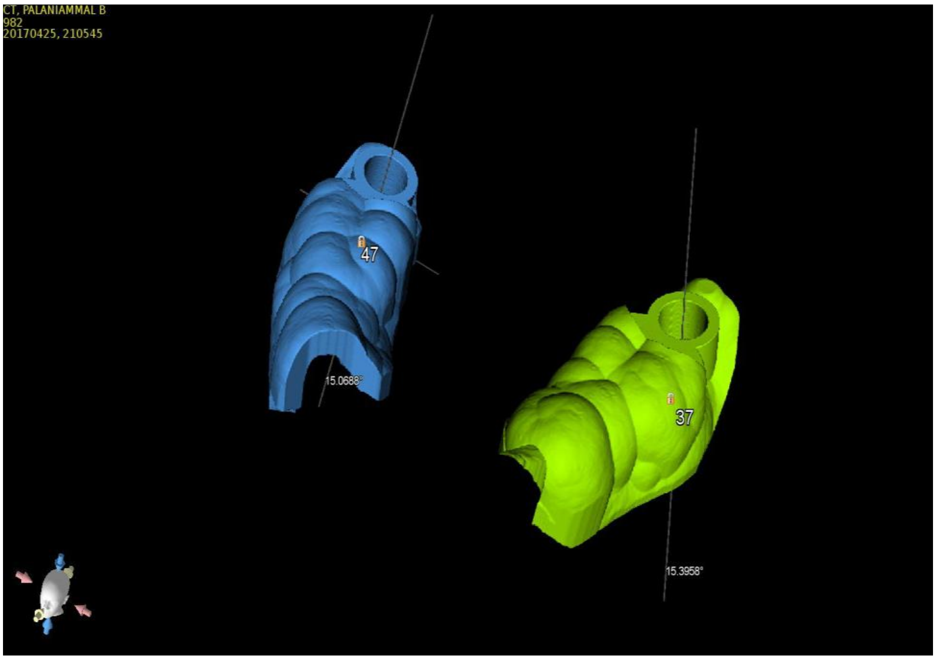
VIRTUAL IMPLANT PLANNING IN THE REGION OF 37 IN RELATION TO INFERIOR ALVEOLAR NERVE (3D RECONSTRUCTION VIEW).



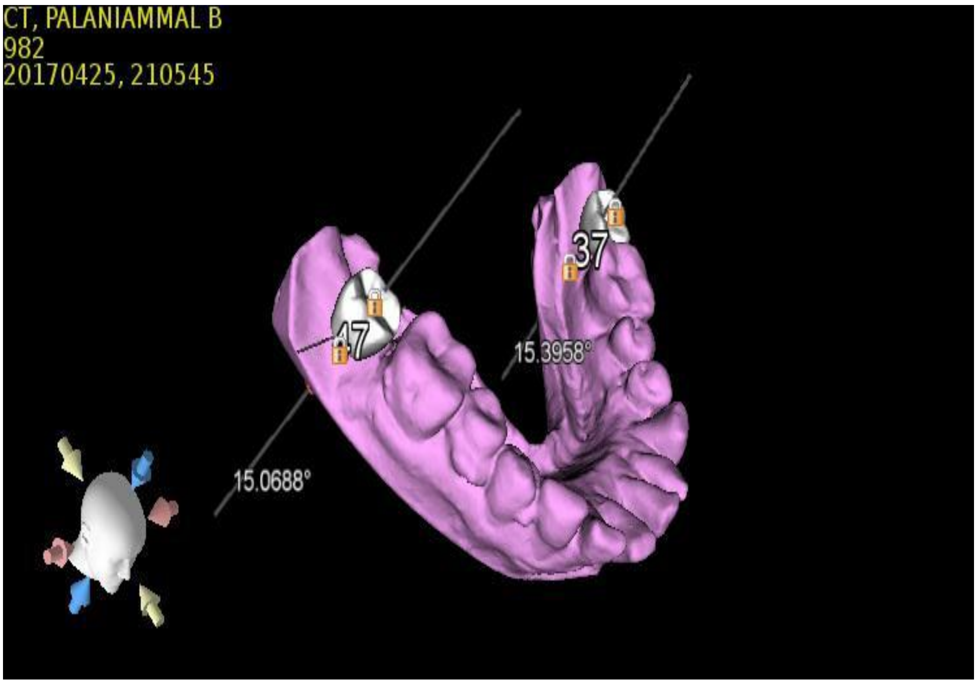
SURGICAL GUIDE PLANNING (3D RECONSRUCTION VIEW).



SURGICAL GUIDE PLANNING (3D RECONSRUCTION VIEW) OF INDIVIDUAL IMPLANT SITES.

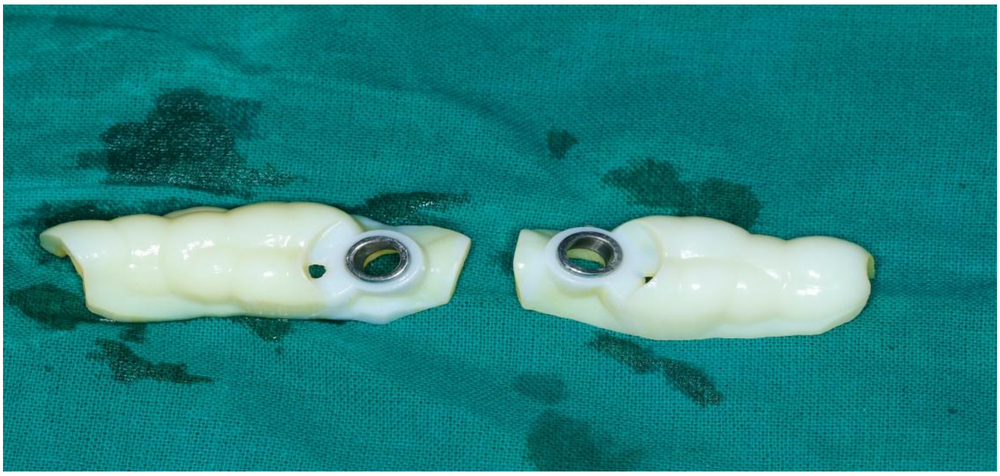


VIRTUAL IMPLANT PLANNING IN 47 REGION (3D RECONSTRUCTION VIEW).



VIRTUAL IMPLANT PLANNING IN 37 REGION (3D RECONSTRUCTION VIEW).

DIGITALLY PLANNED 3D PRINTED SURGICAL STENT.



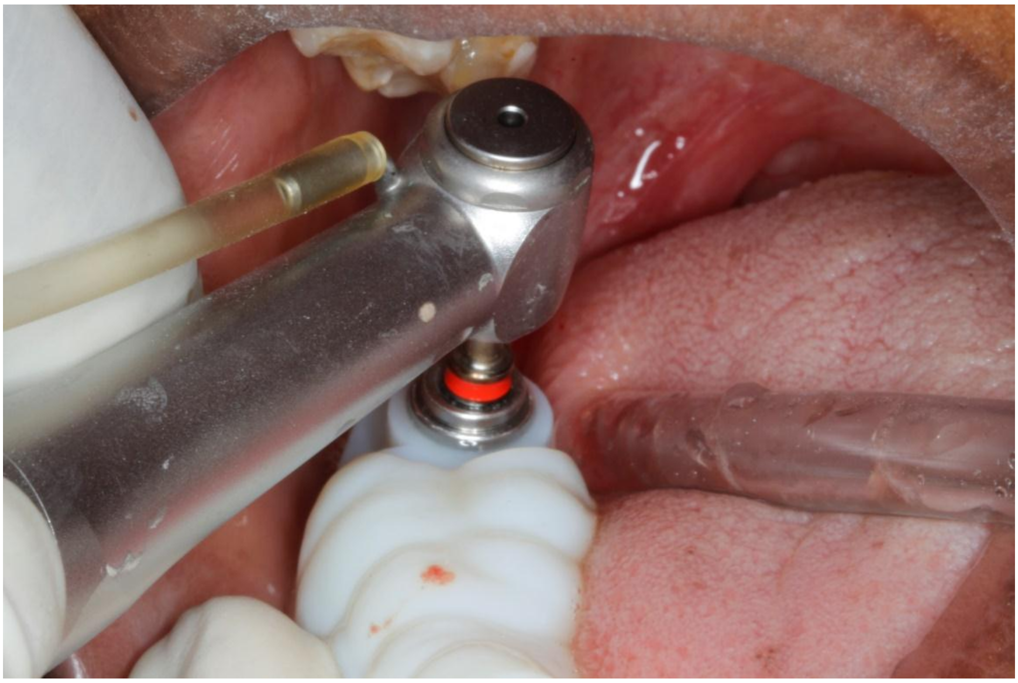
CYLINDRICAL DRILL SLEEVES (2.1mm,3.0mm,3.5mm,4.4mm).

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL VIA 2MM DIAMETER DRILL SLEEVE.

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL VIA 3.5 MM DIAMETER DRILL SLEEVE.

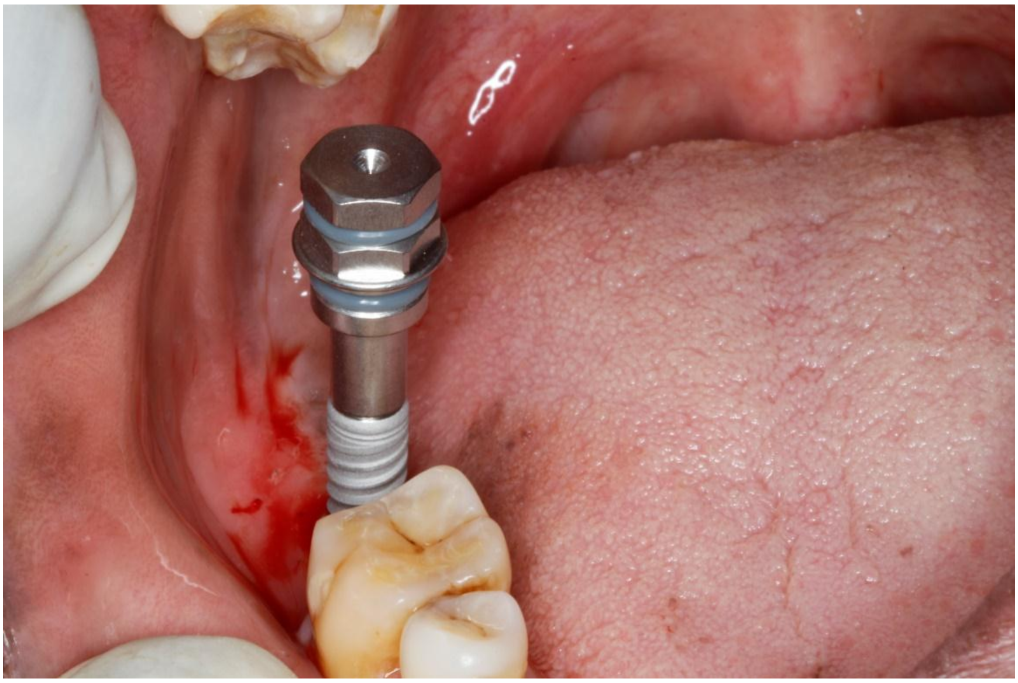
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8 MM DRILL VIA 3.0 MM DIAMETER DRILL SLEEVE.

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL VIA 4.0MM DIAMETER DRILL SLEEVE.

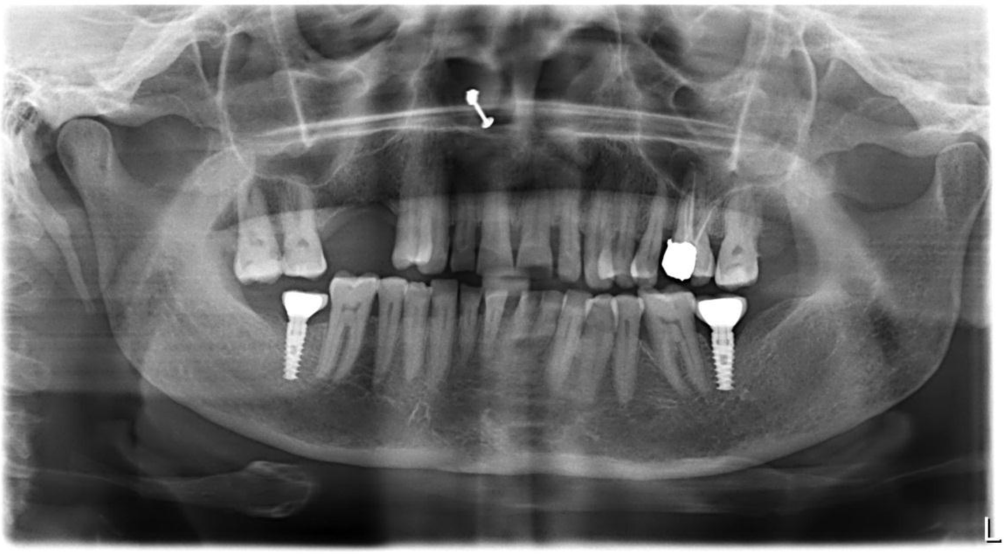


SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.6MM DRILL VIA 4.0MM DIAMETER DRILL SLEEVE.

IMPLANT INSERTION WITH IMPLANT MOUNT .

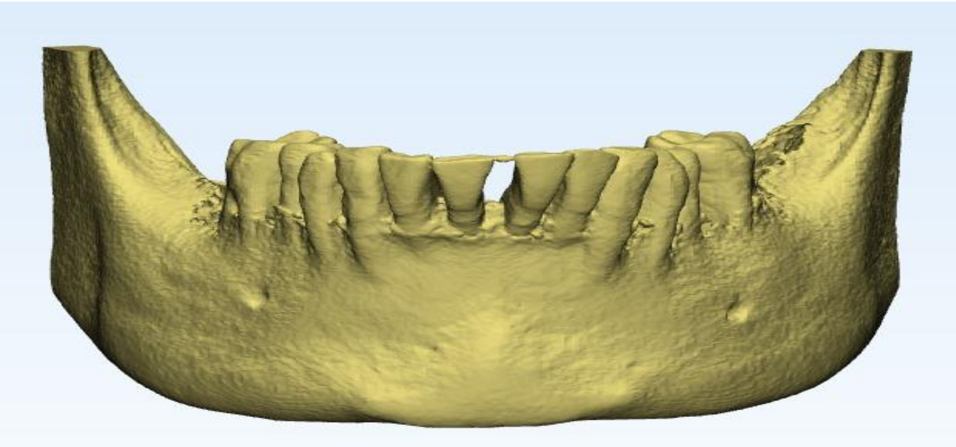


POSTOPERATIVE OPG AFTER 4 MONTHS OF PLACING CROWN.

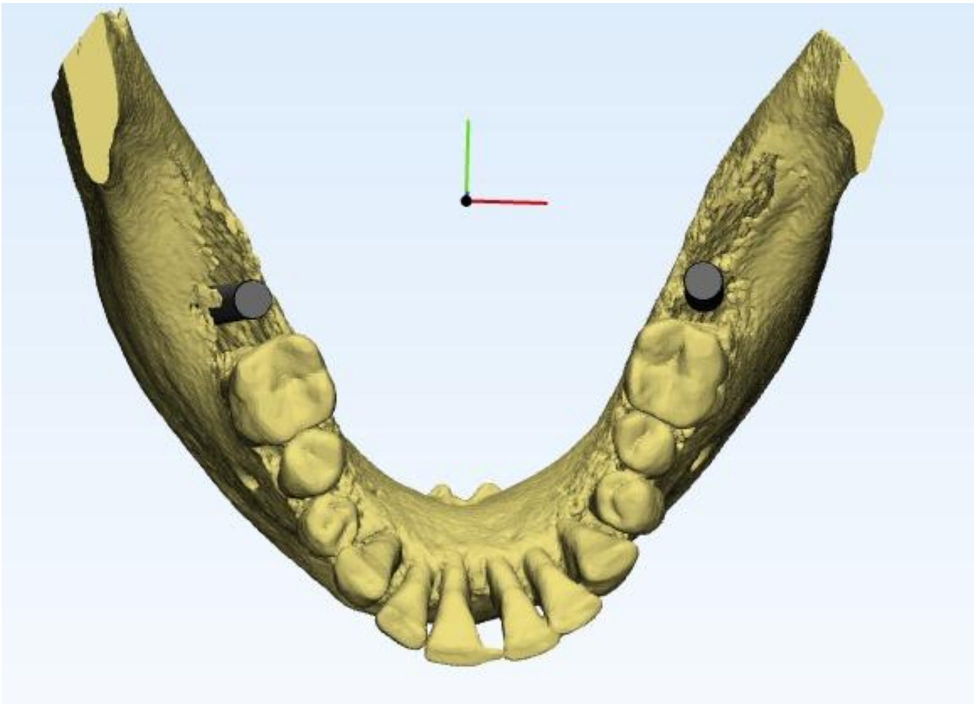


SUPERIMPOSITION OF VIRTUAL PLANNING AND POSTOPERATIVE CBCT IN 3D.

3D RECONSTRUCTION MODEL OF PARTIALLY EDENTULOUS MANDIBLE.



VIRTUAL PLANNING OF IMPLANTS IN THE LEFT AND RIGHT MANDIBULAR REGION(OCCLUSAL VIEW).



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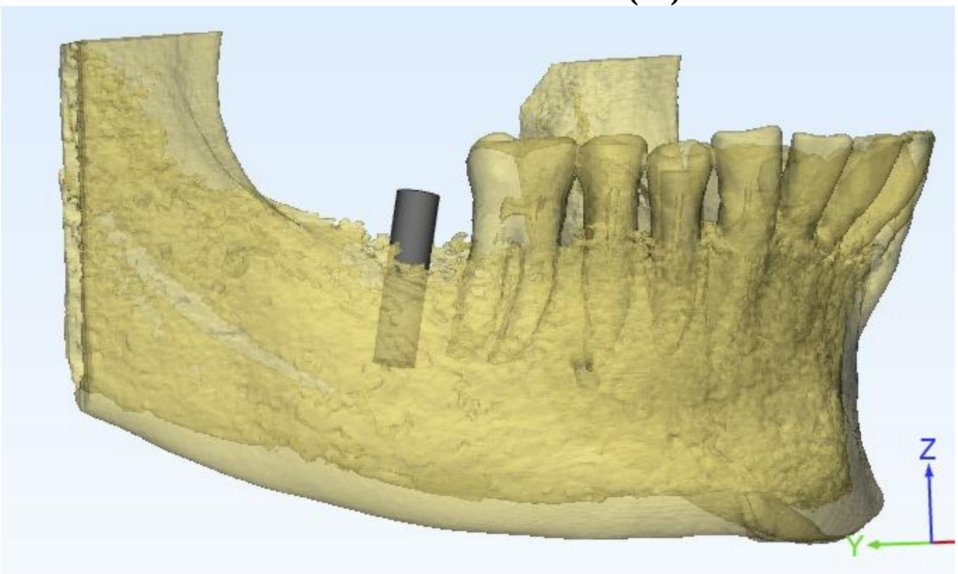
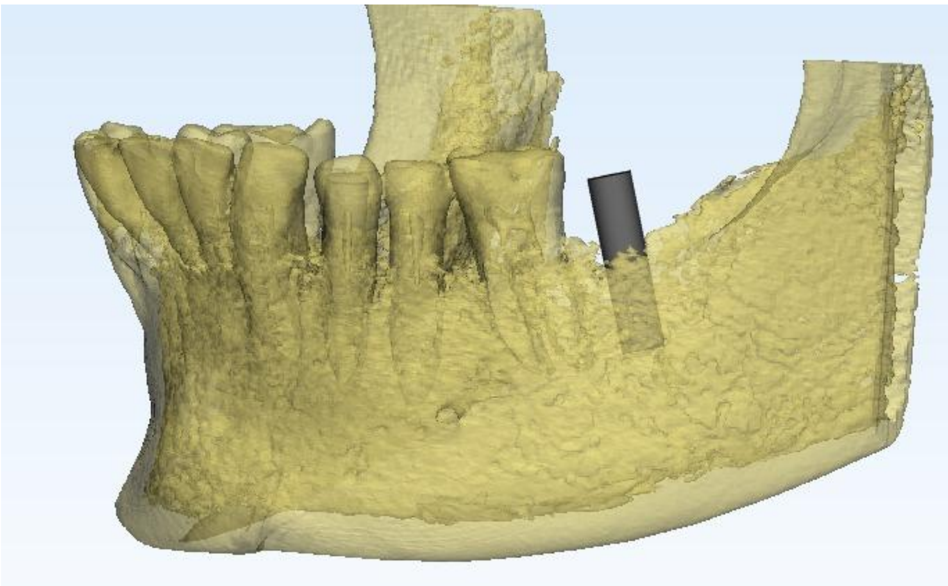
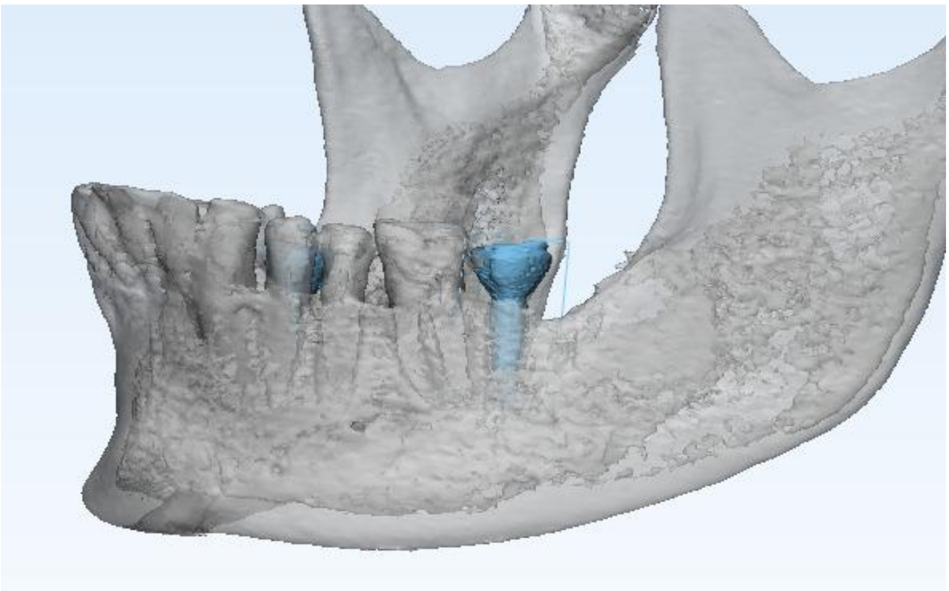
VIRTUAL PLANNING OF IMPLANTS IN THE RIGHT MANDIBULAR REGION(47).



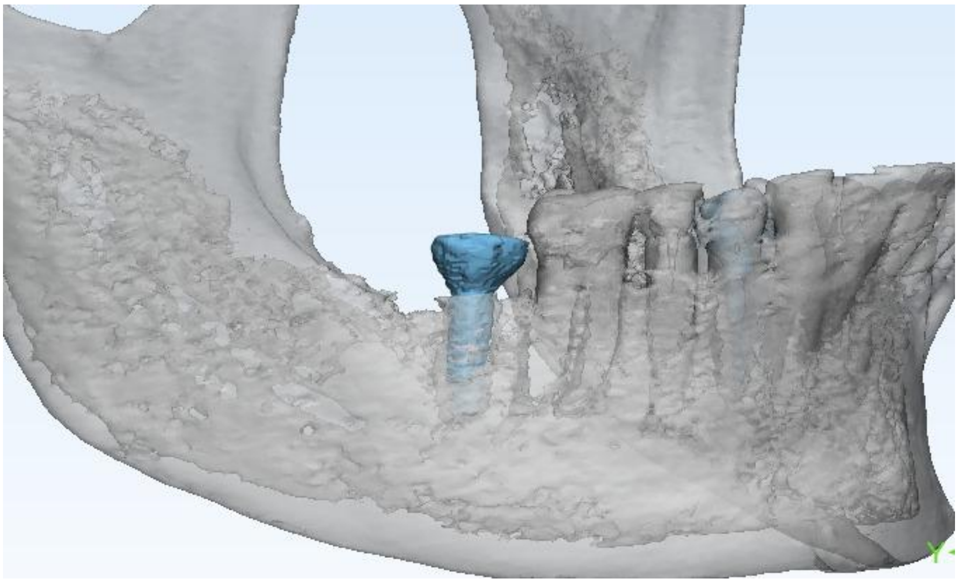
VIRTUAL PLANNING OF IMPLANTS IN THE LEFT MANDIBULAR REGION(37).



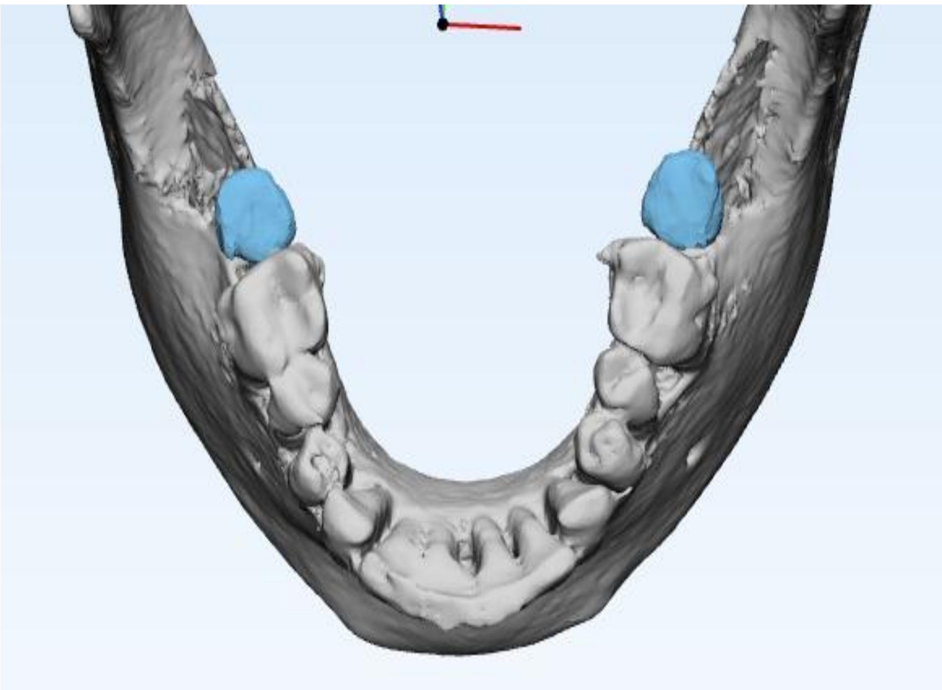
ACTUAL PLACEMENT OF IMPLANTS WITH CROWN IN THE RIGHT POSTERIOR MANDIBULAR REGION(37).



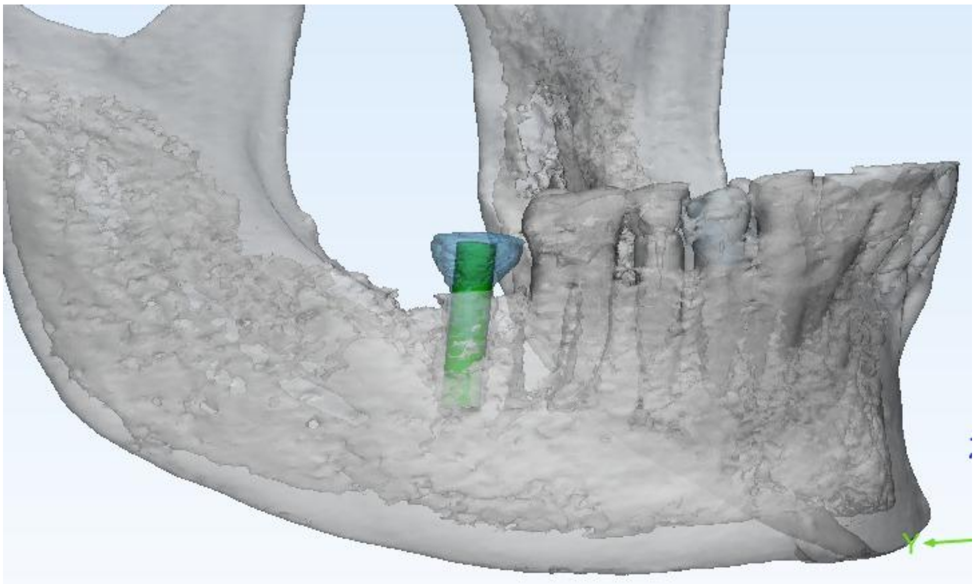
ACTUAL PLACEMENT OF IMPLANTS WITH CROWN IN THE RIGHT POSTERIOR MANDIBULAR REGION(47).



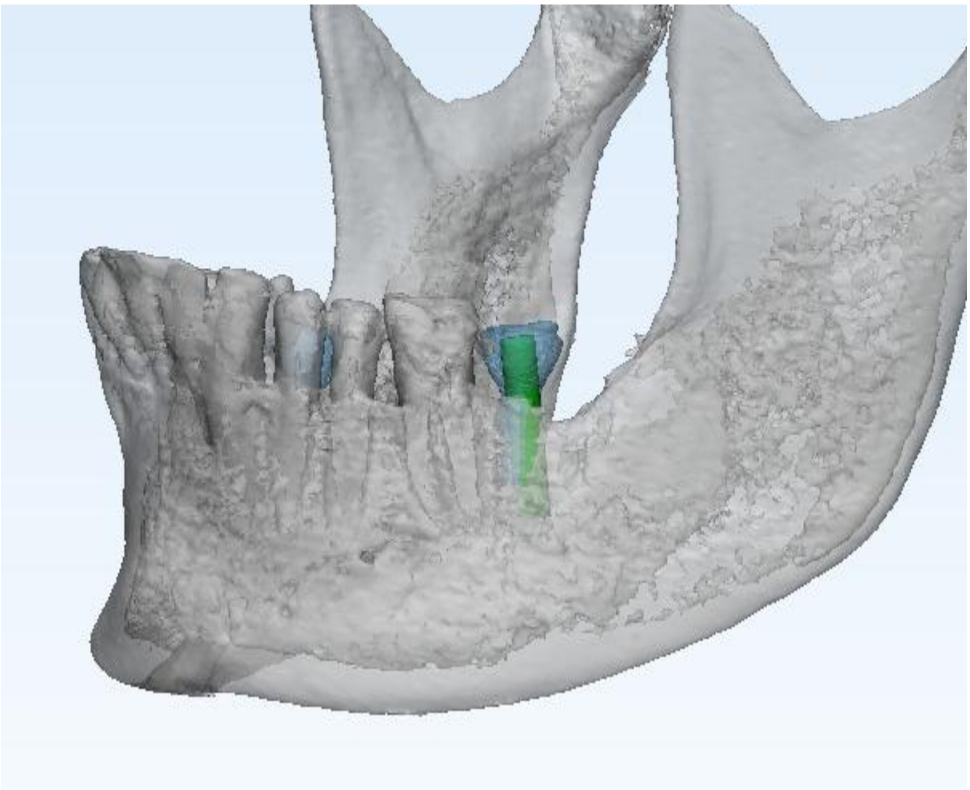
ACTUAL PLACEMENT OF IMPLANTS WITH CROWN IN THE RIGHT AND LEFT POSTERIOR MANDIBULAR REGION (47 AND 37)-OCCLUSAL VIEW.



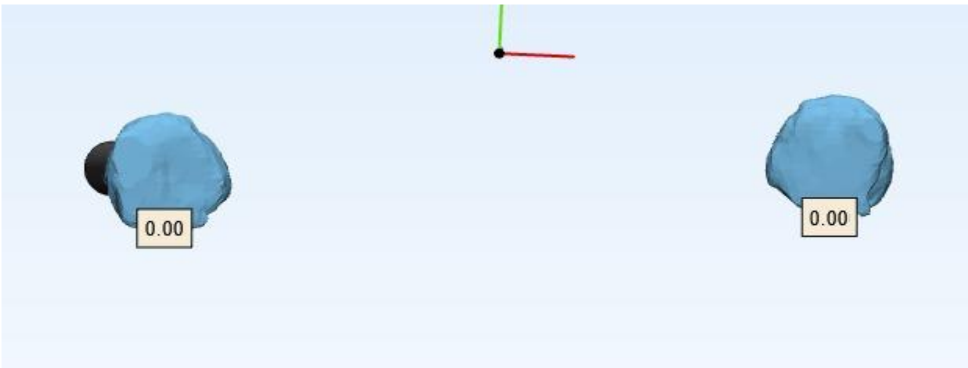
SUPERIMPOSING OF ACTUAL IMPLANT OVER VIRTUALLY PLANNED IMPLANT POSITION IN THE RIGHT POSTERIOR MANDIBULAR REGION (47).



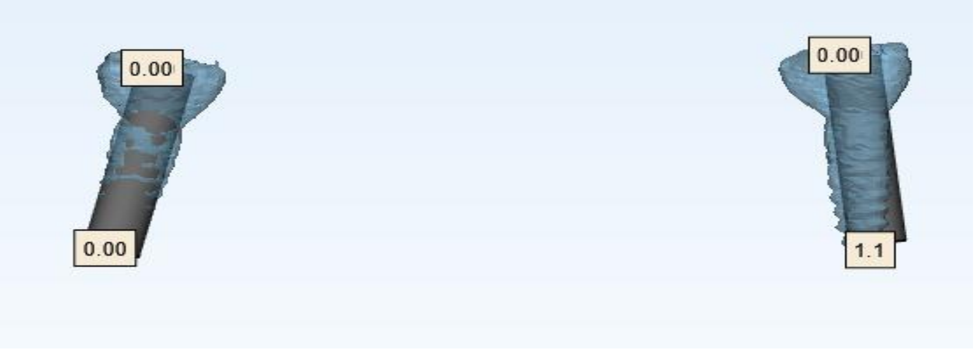
SUPERIMPOSING OF ACTUAL IMPLANT OVER VIRTUALLY PLANNED IMPLANT POSITION IN THE LEFT POSTERIOR MANDIBULAR REGION (37).



DEVIATION OF THE IMPLANTS AT CREST(IN MM).

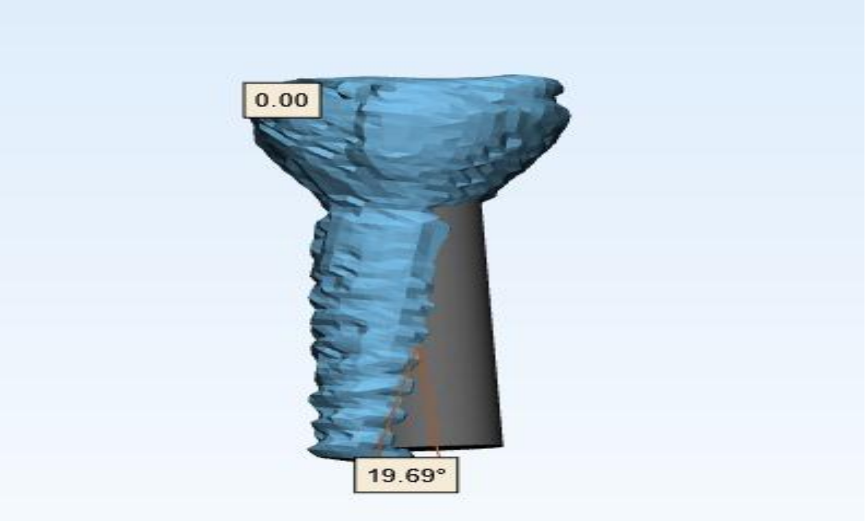


DEVIATION OF LEFT AND RIGHT POSTERIORLY PLACED IMPLANTS AT CREST AND APEX(IN MM).

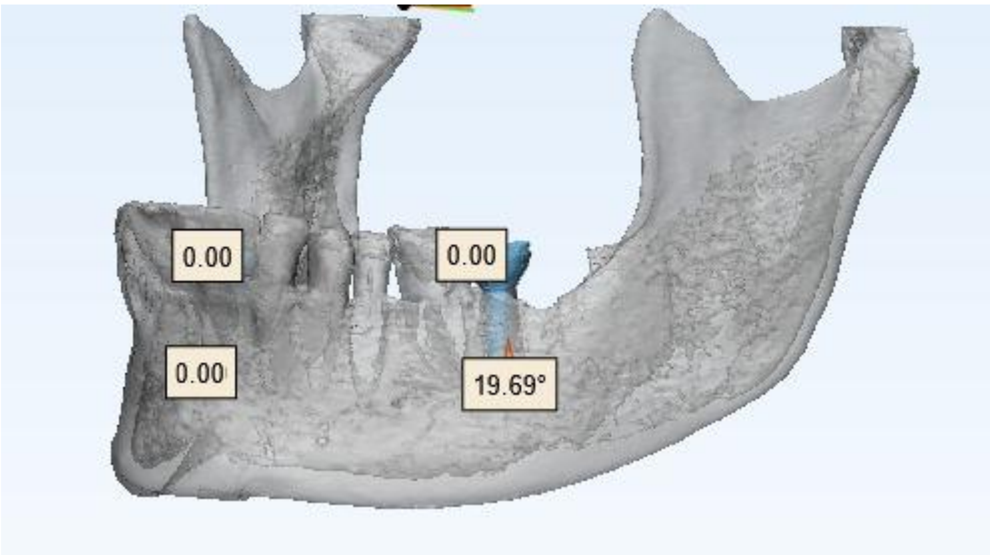


DEVIATION OF THE IMPLANTS AT CREST(IN MM).

ANGULATION OF THE LEFT POSTERIORLY PLACED IMPLANT AT REST AND APEX (IN DEGREES).

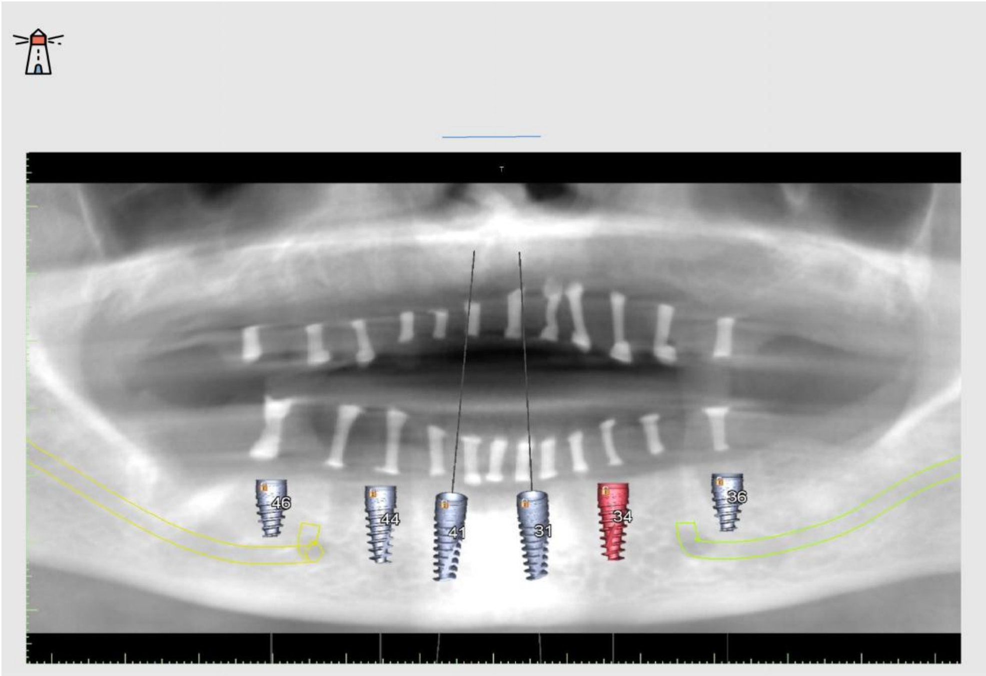


ANGULATION OF THE IMPLANTS AT CREST AND APEX (IN DEGREES).

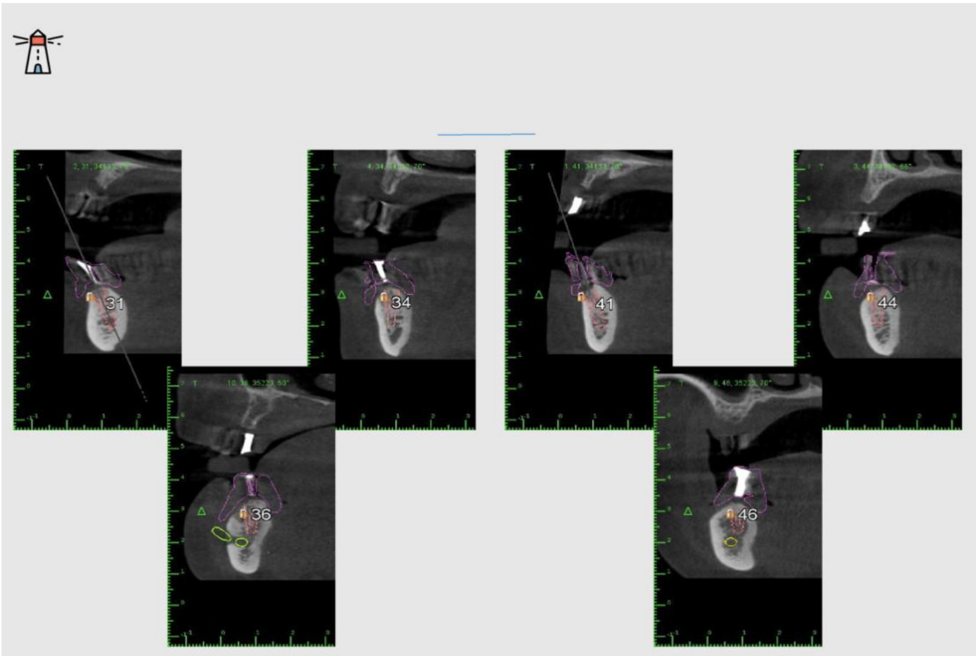


CASE 2

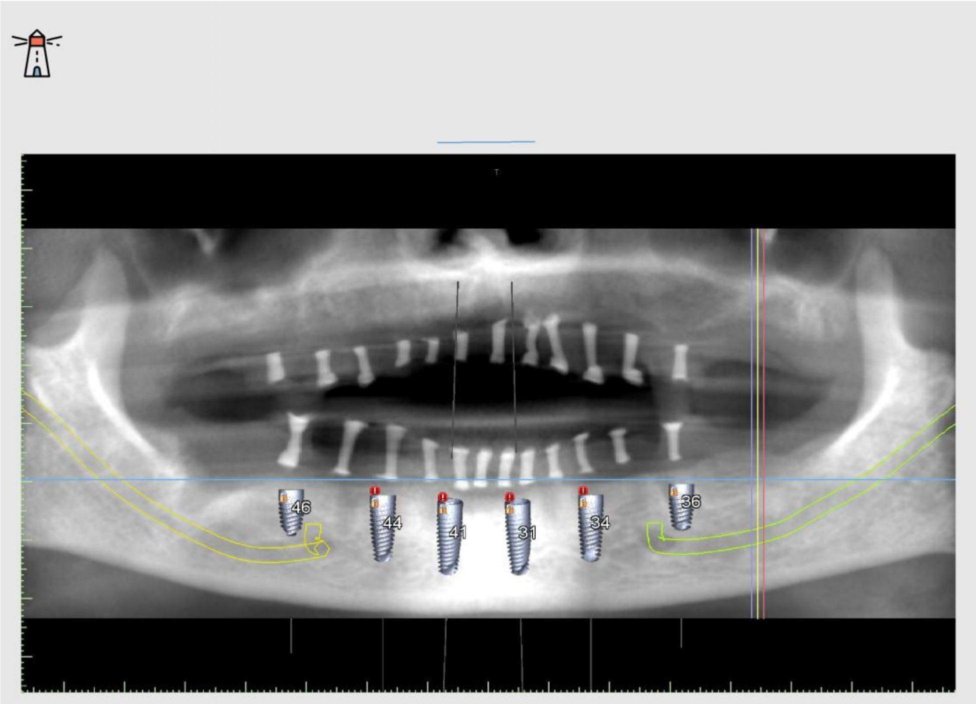
VIRTUAL PLANNING OF PREOPERATIVE CBCT FOR MANDIBLE.



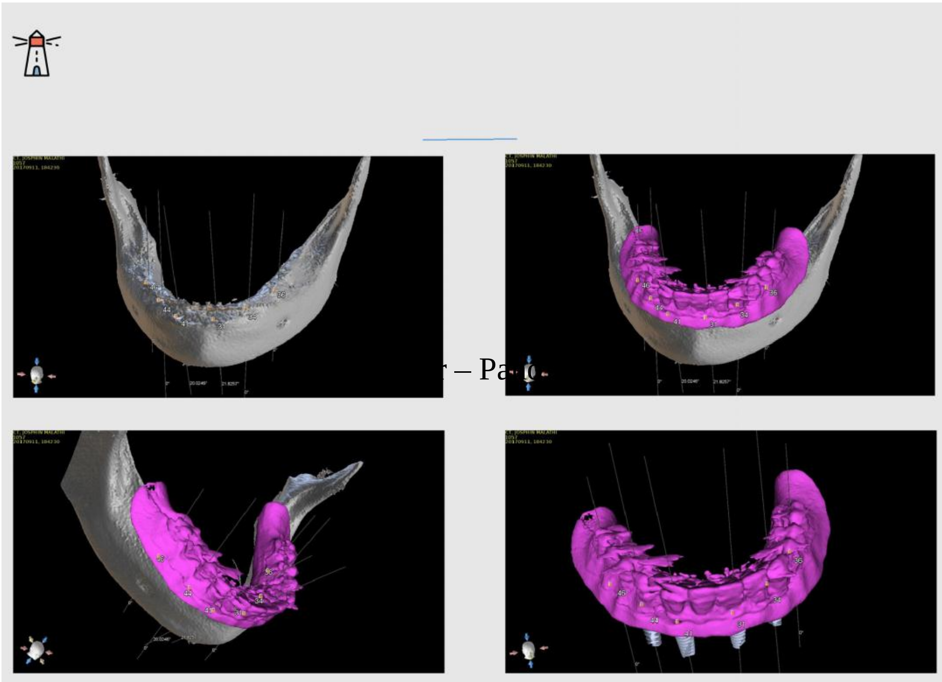
VIRTUAL IMPLANT PLANNING IN THE REGION OF 31, 34, 36, 41, 44, 46(CORONAL VIEW).



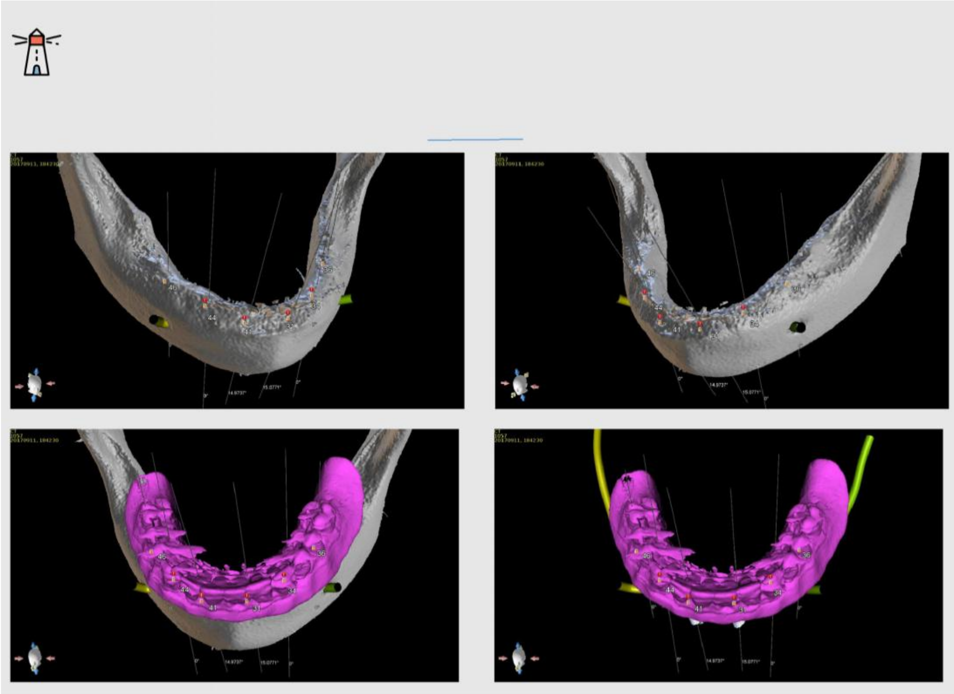
VIRTUAL IMPLANT PLANNING IN MANDIBLE (PANORAMIC VIEW).



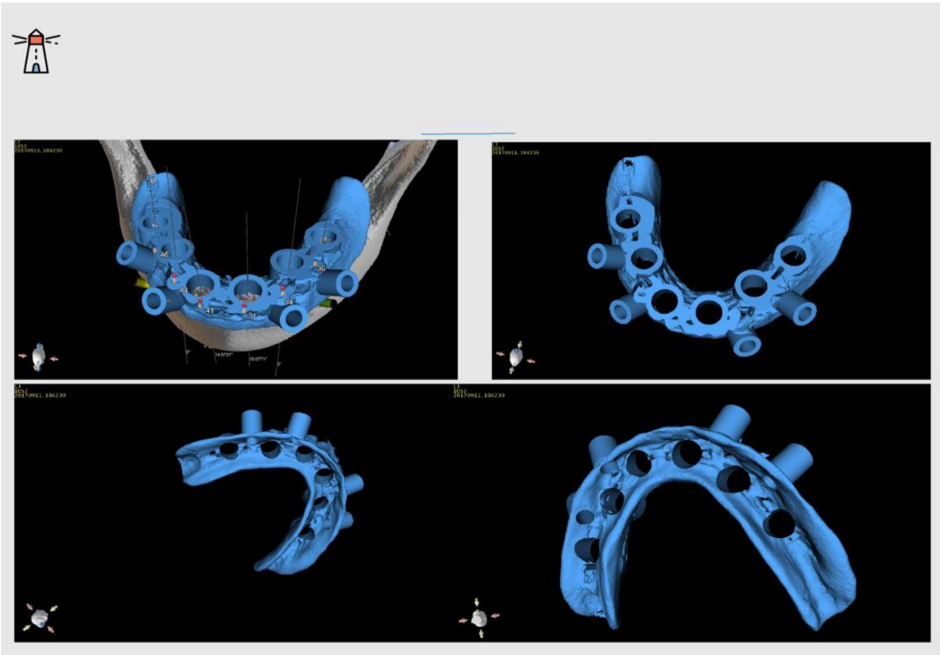
3D RECONSTRUCTION VIEW OF MANDIBLE.



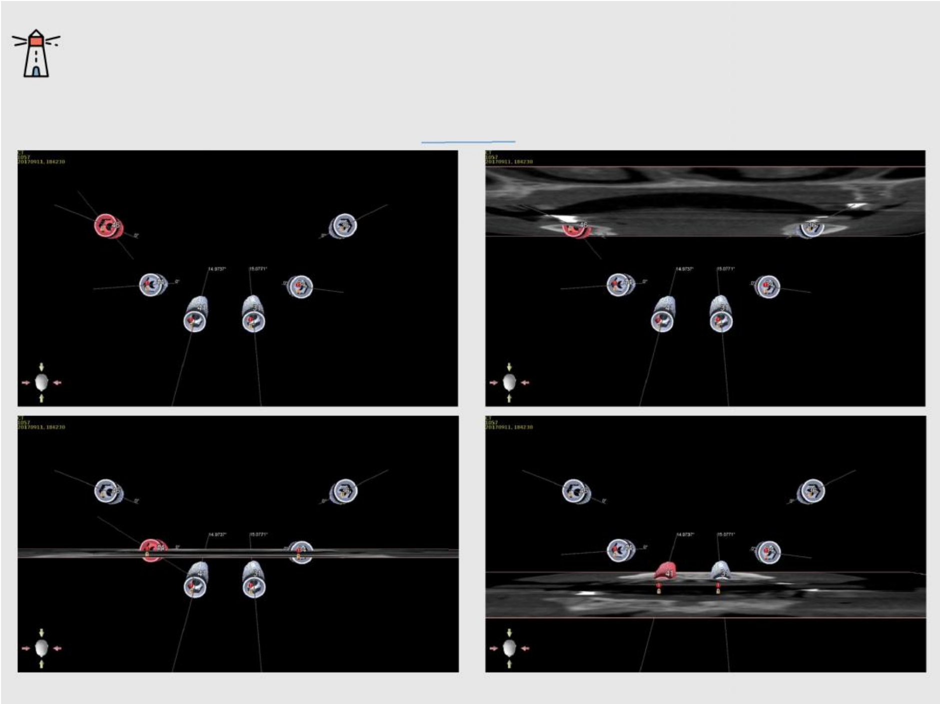
3D RECONSTRUCTION VIEW OF MANDIBLE.



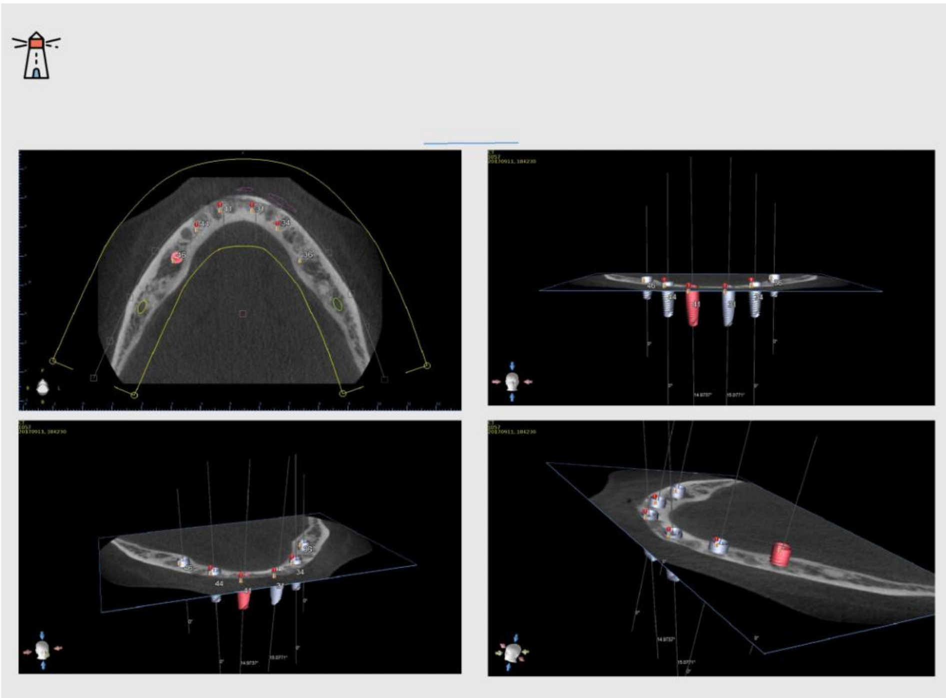
VIRTUAL PLANNING OF 3D GUIDE.



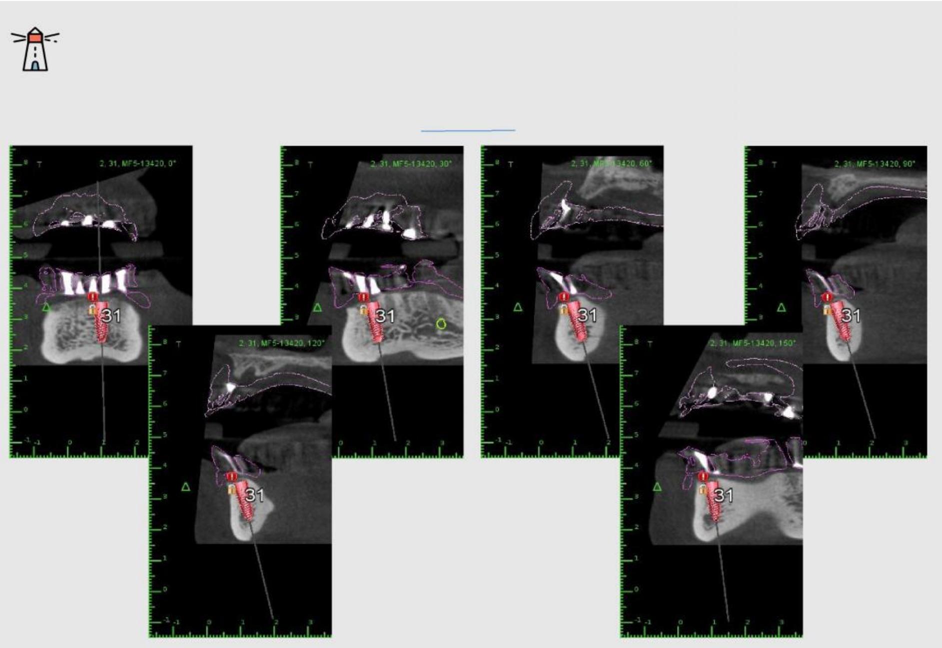
ALIGNMENT OF IMPLANTS (VIRTUAL PLANNING)-CORONAL PLANE.



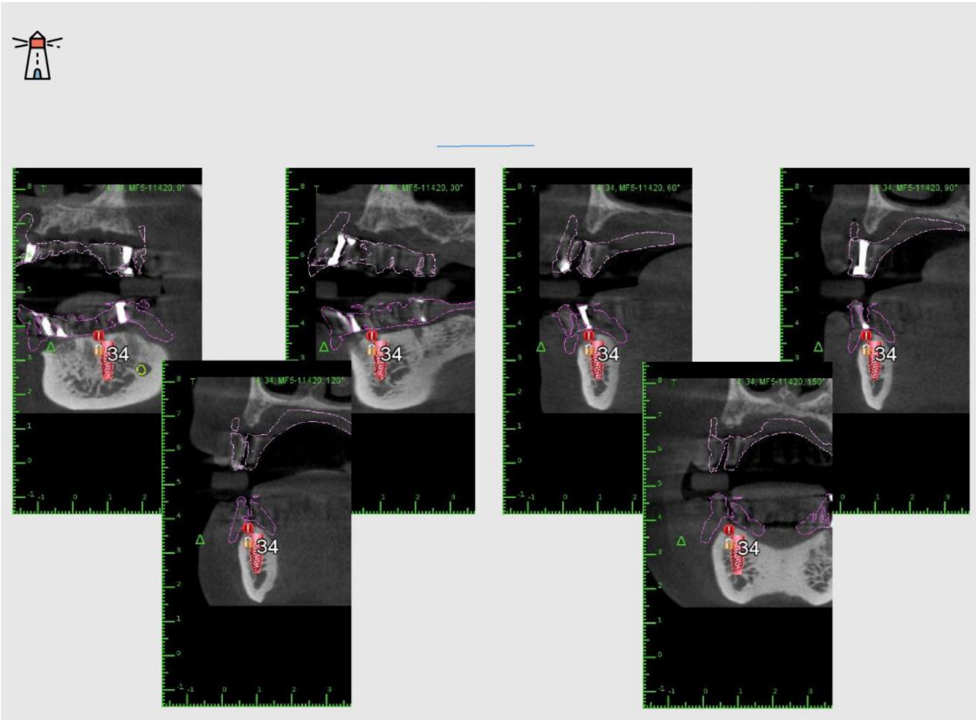
ALIGNMENT OF IMPLANT S (VIRTUAL PLANNING)-CORONAL PLANE.



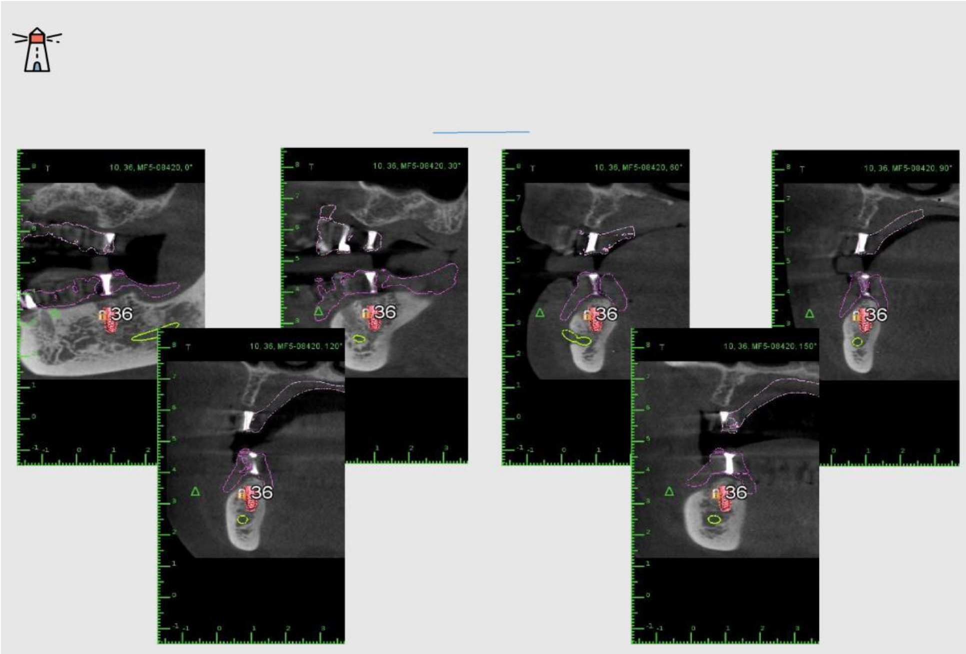
VIRTUAL IMPLANT PLANNING IN THE REGION OF 31-30 DEGREE ROTATION VIEW.



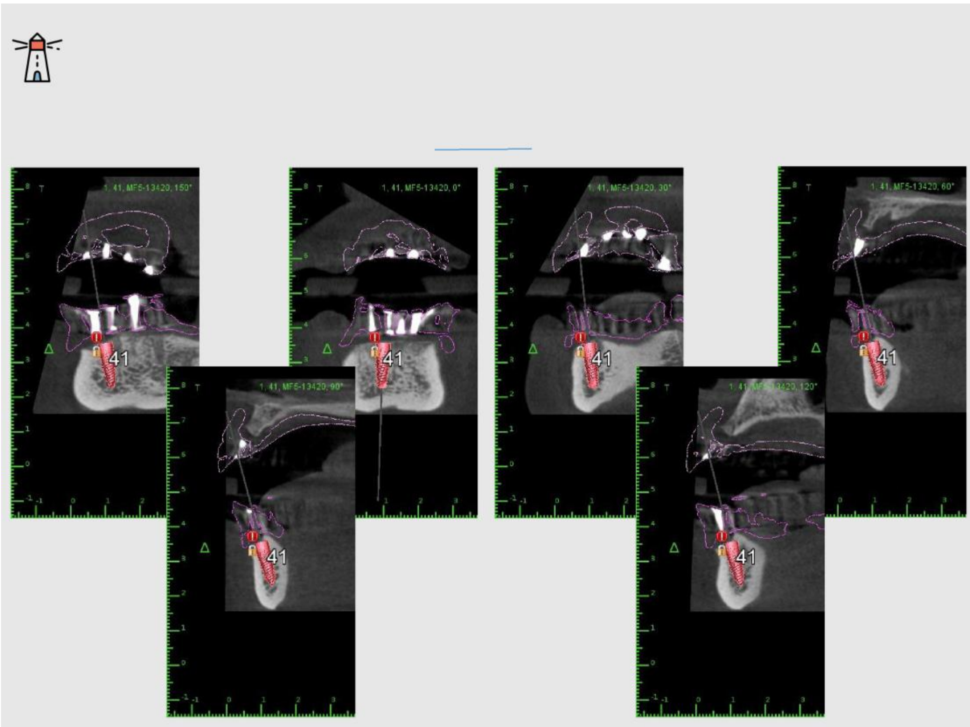
VIRTUAL IMPLANT PLANNING IN THE REGION OF 34-30 DEGREE ROTATION VIEW.



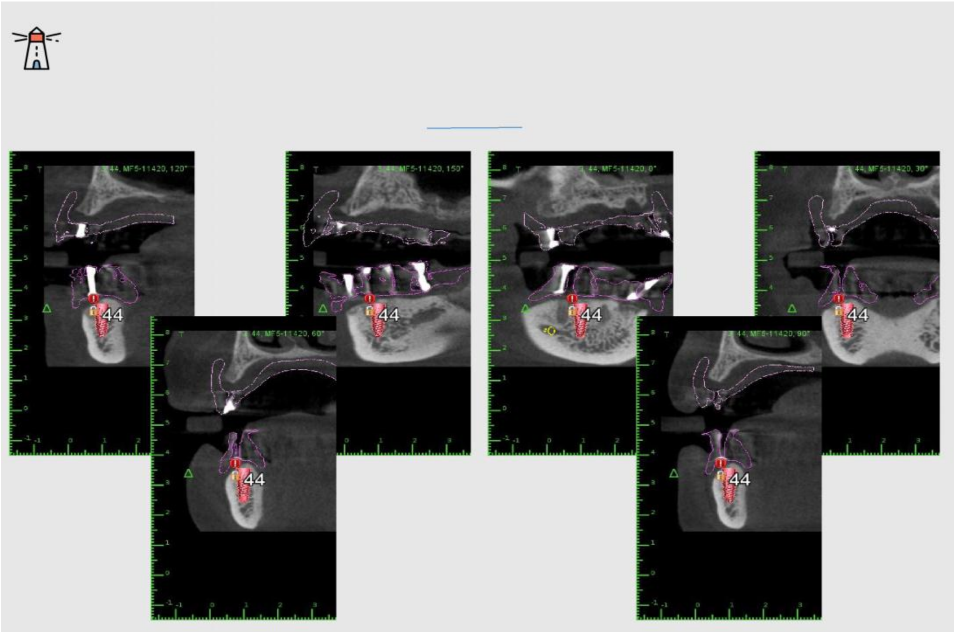
VIRTUAL IMPLANT PLANNING IN THE REGION OF 36-30 DEGREE ROTATION VIEW.



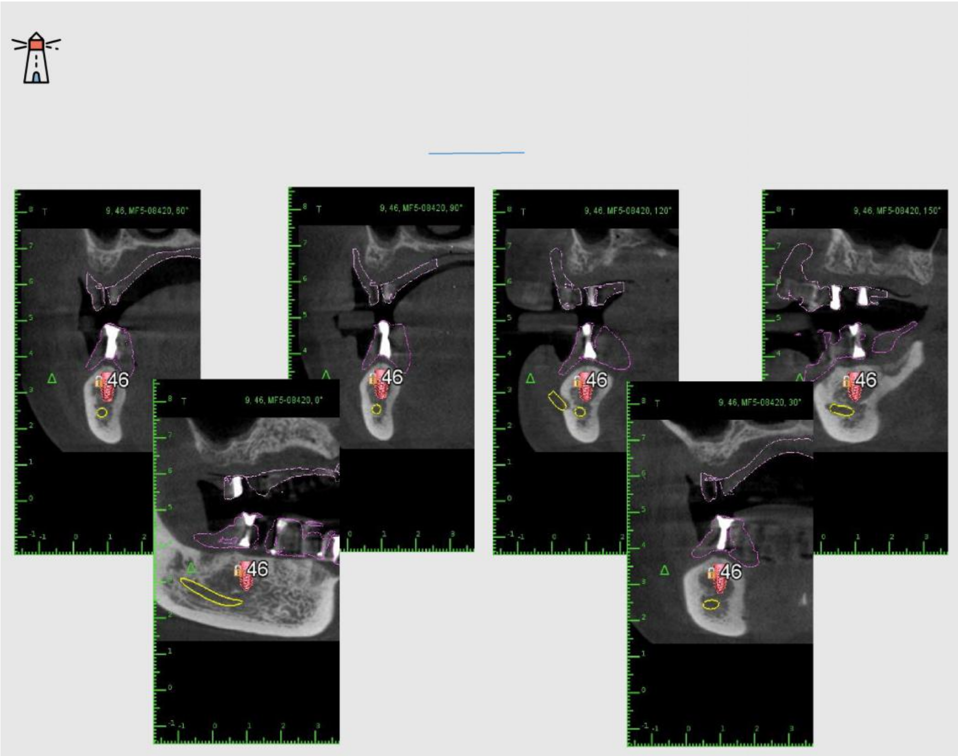
VIRTUAL IMPLANT PLANNING IN THE REGION OF 41-30 DEGREE ROTATION VIEW.



VIRTUAL IMPLANT PLANNING IN THE REGION OF 44-30 DEGREE ROTATION VIEW.

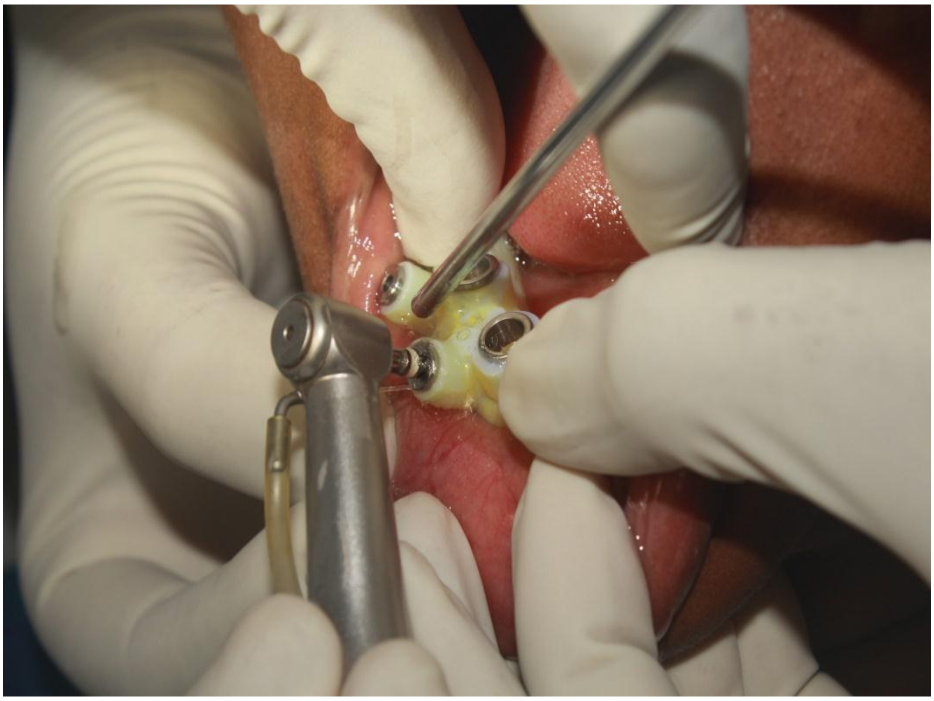


VIRTUAL IMPLANT PLANNING IN THE REGION OF 46-30 DEGREE ROTATION VIEW.

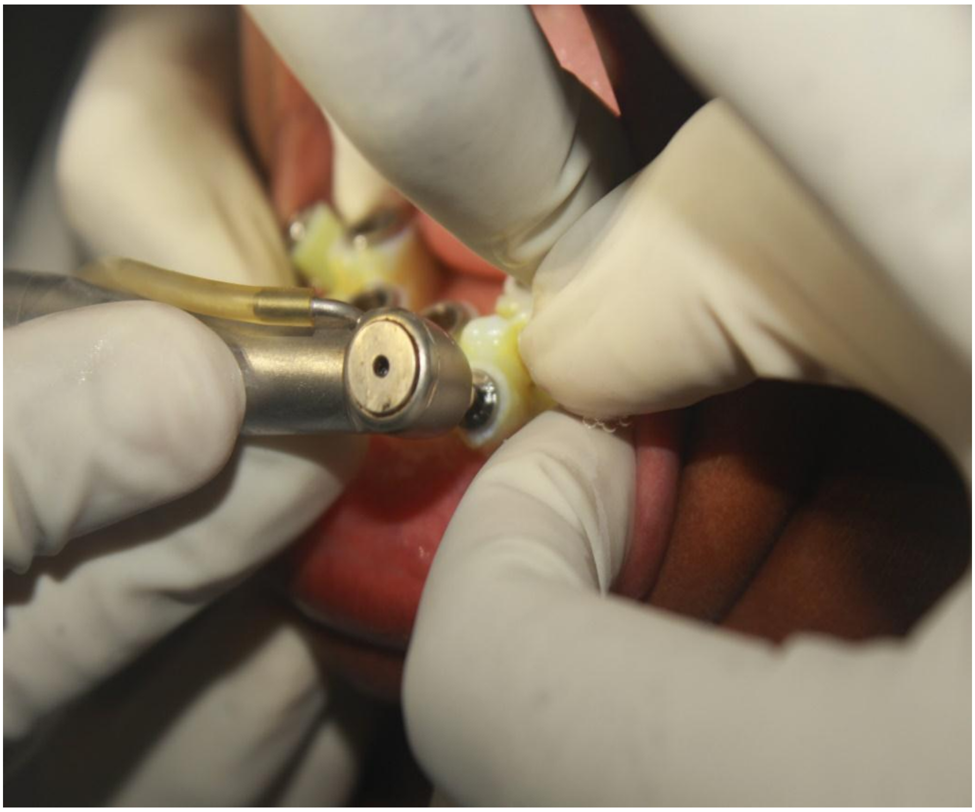


SURGICAL GUIDE PLACED IN EDENTULOUS MANDIBLE.

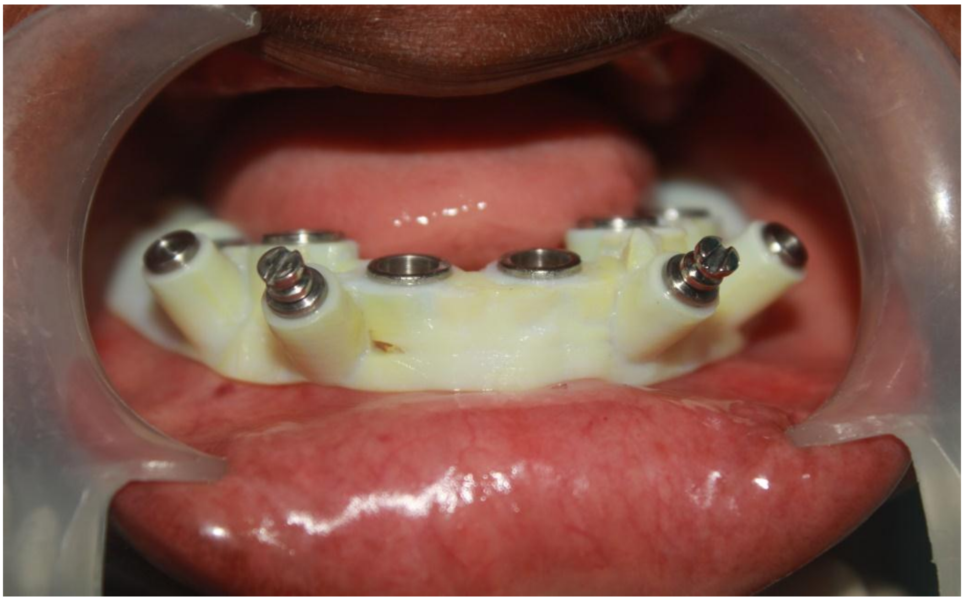
SURGICAL DRILLING DONE FOR THE PLACEMENT OF ANCHORING PINS IN THE LABIAL PART OF MANDIBLE.



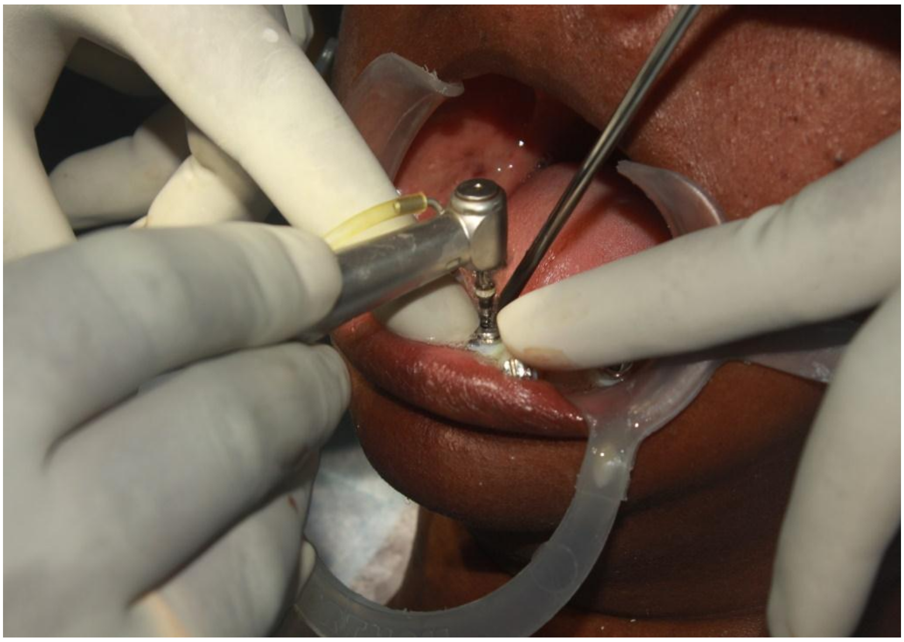
ANCHORING PINS PLACED FOR THE STABILIZATION OF SURGICAL GUIDE IN THE EDENTULOUS MANDIBLE.



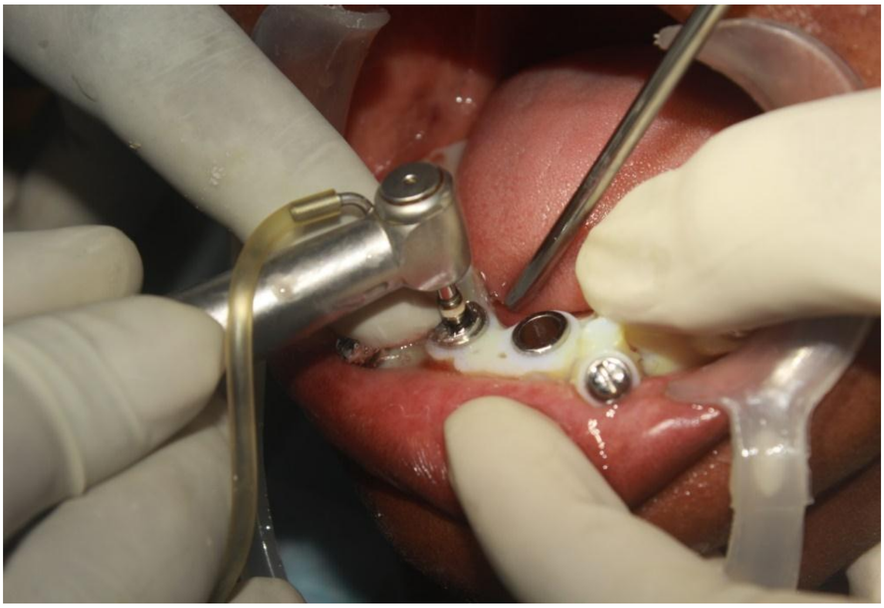
SURGICAL GUIDE FIXED USING ANCHORING PINS.



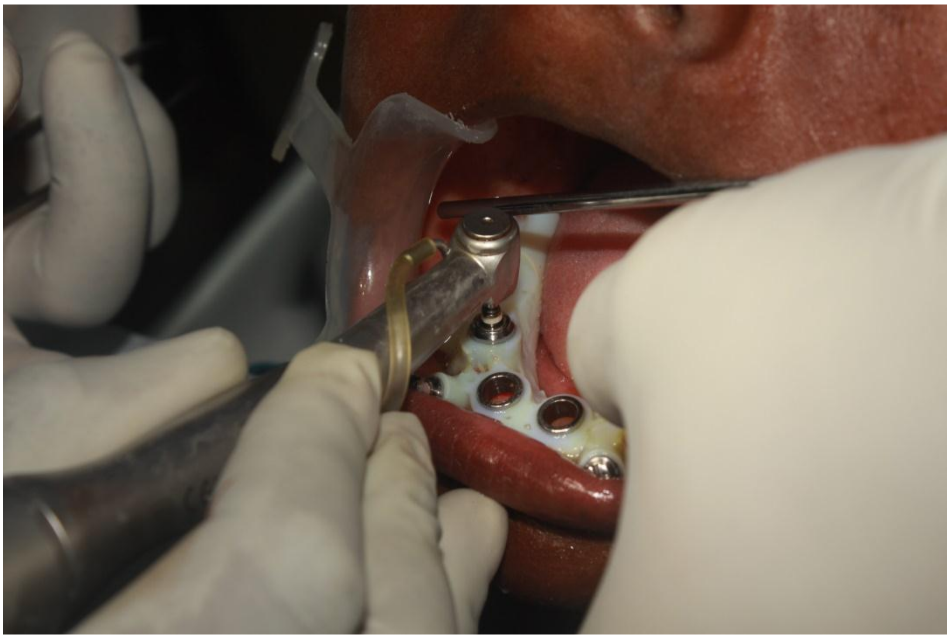
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 32.



SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 42.

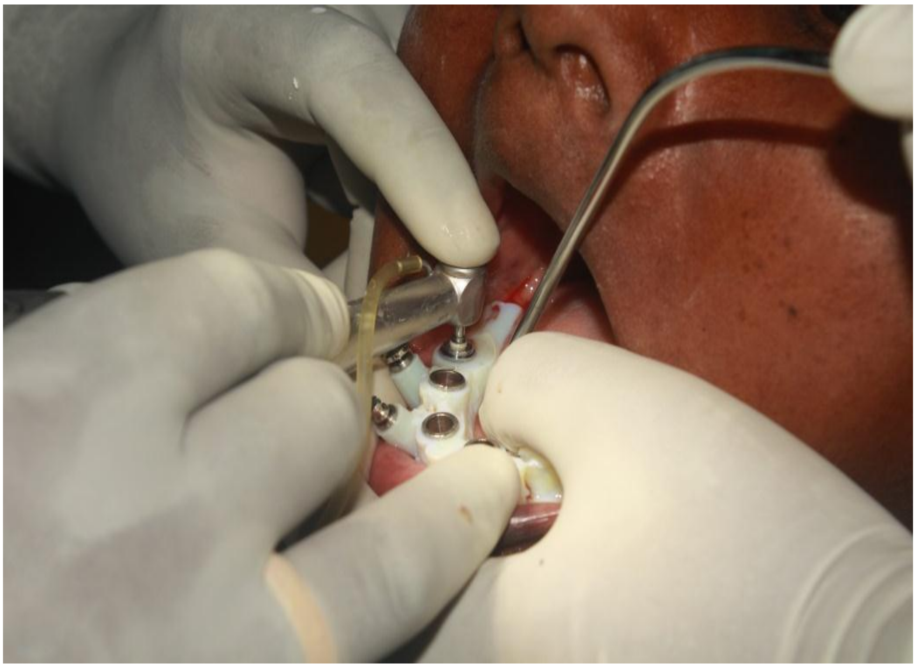


SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 44.



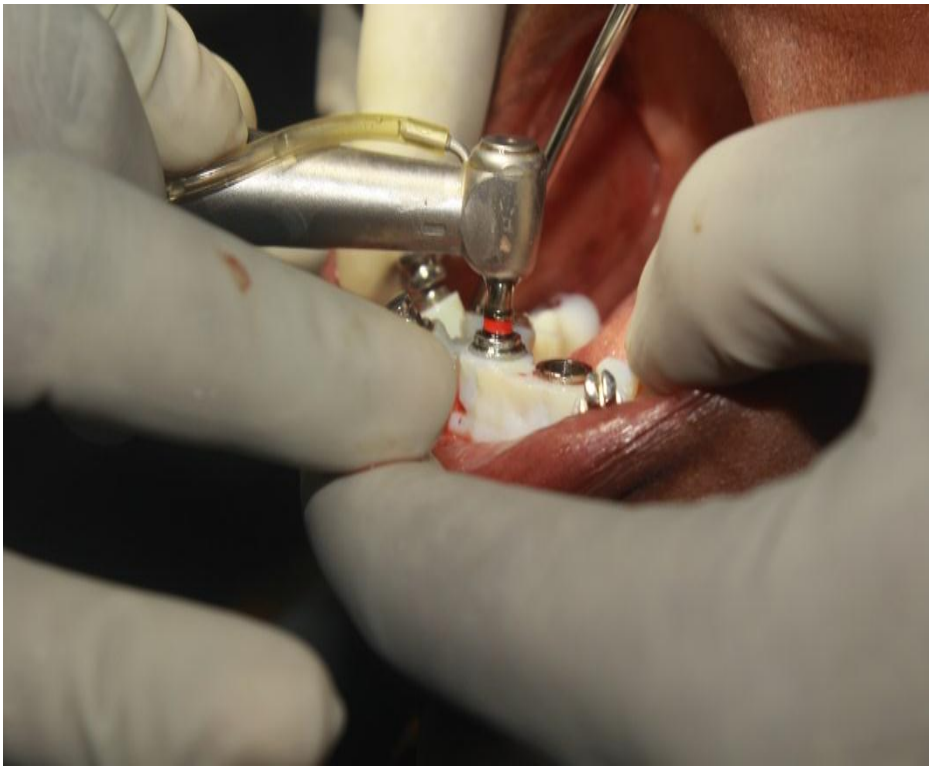
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 32.

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 46.



SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2MM DRILL IN THE REGION OF 44.

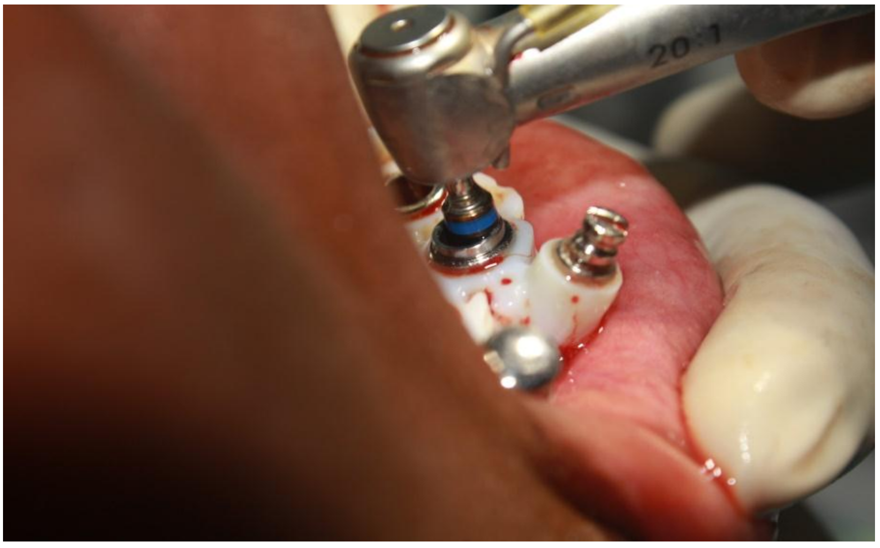
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL IN THE REGION OF 42.



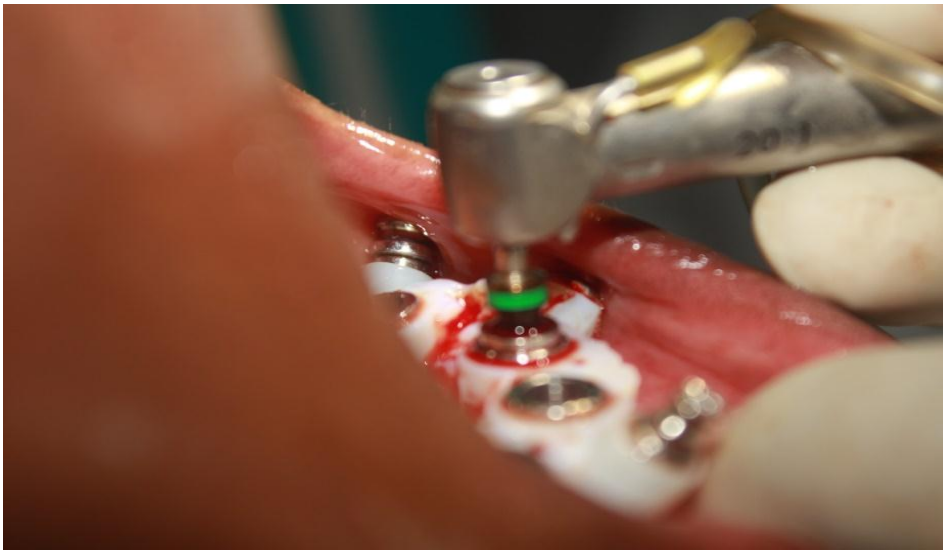
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL IN THE REGION OF 46.

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL IN THE REGION OF 44.

SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.2MM DRILL IN THE REGION OF 32.

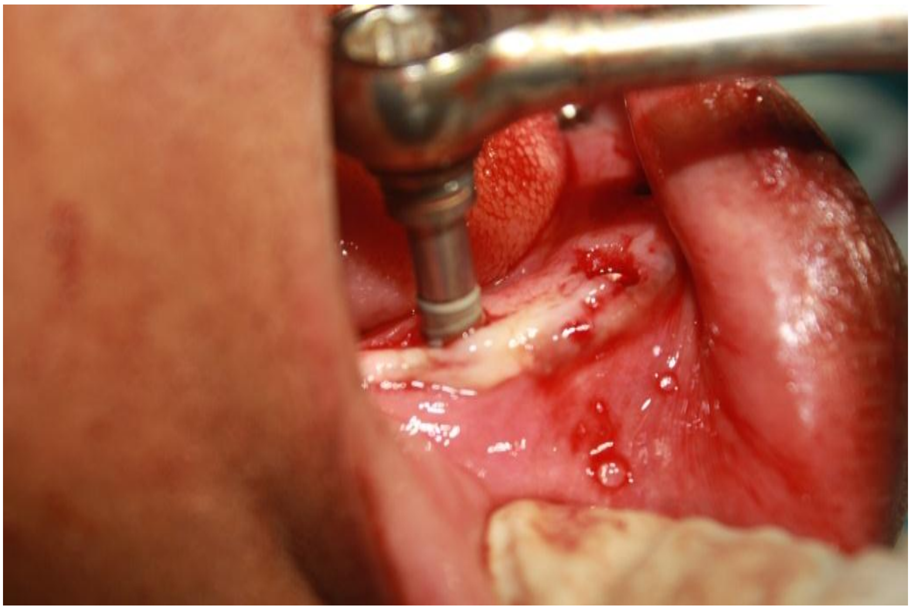


SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.6MM DRILL IN THE REGION OF 42 .



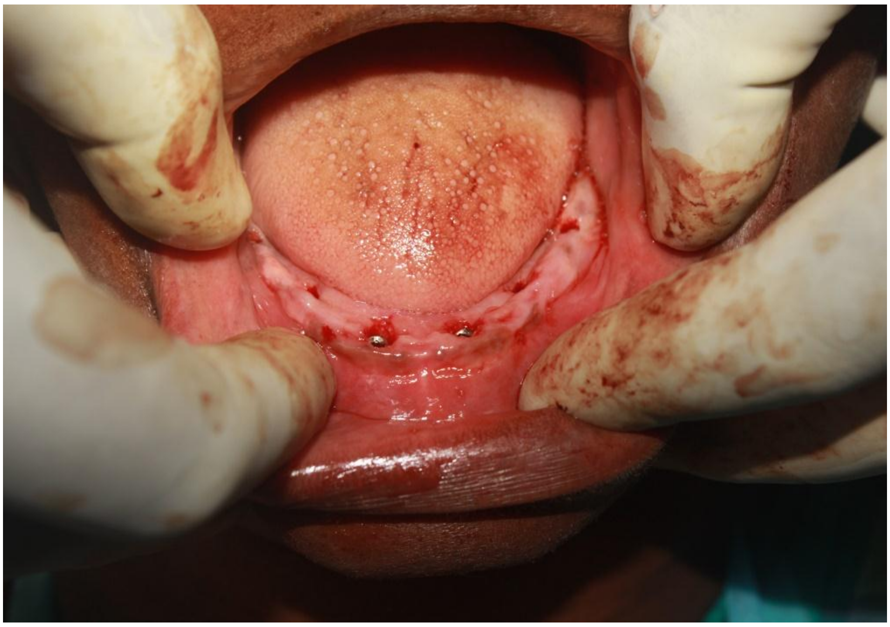
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.2MM DRILL IN THE REGION OF 32.

INSERTION OF IMPLANT USING HAND WRENCH.



IMPLANT PRIOR TO MOUNT REMOVAL.

FINAL PLACEMENT OF IMPLANTS IN MANDIBLE.

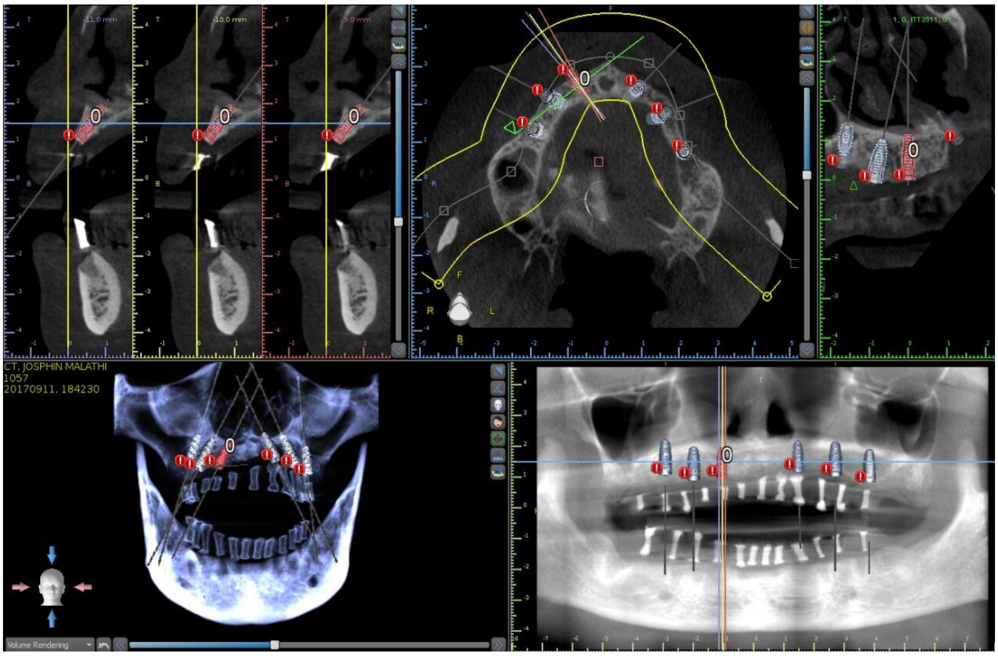


POST OPERATIVE HEALING AFTER THREE DAYS.

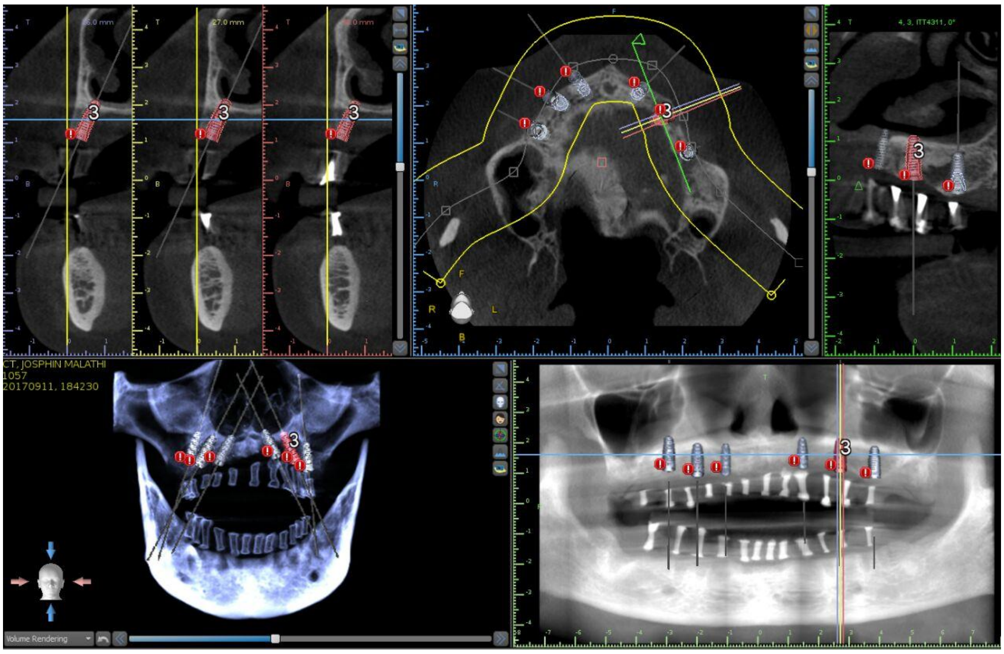
COVER SCREWS REMOVED AFTER 3 MONTHS FOR THE PLACEMENT OF HEALING ABUTMENT.

HEALING ABUTMENT PLACED.

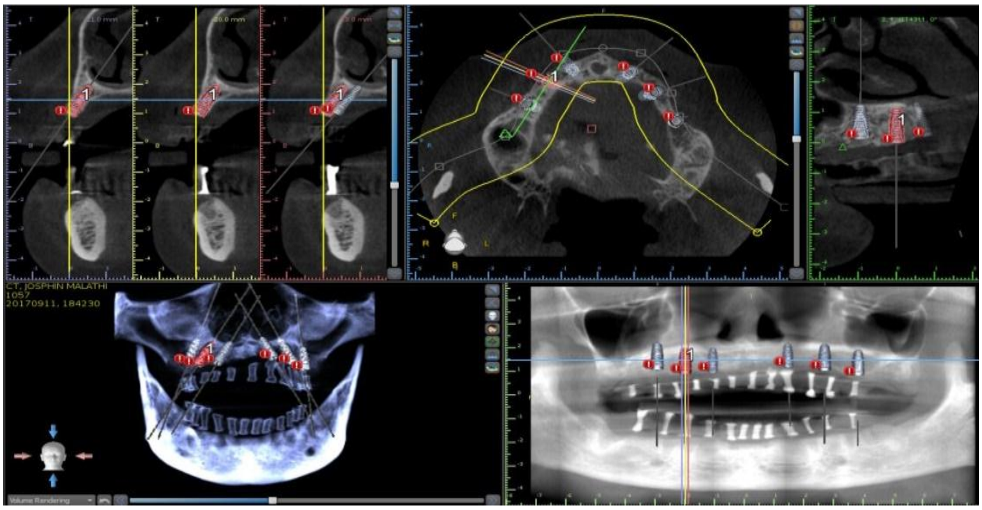
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 12.



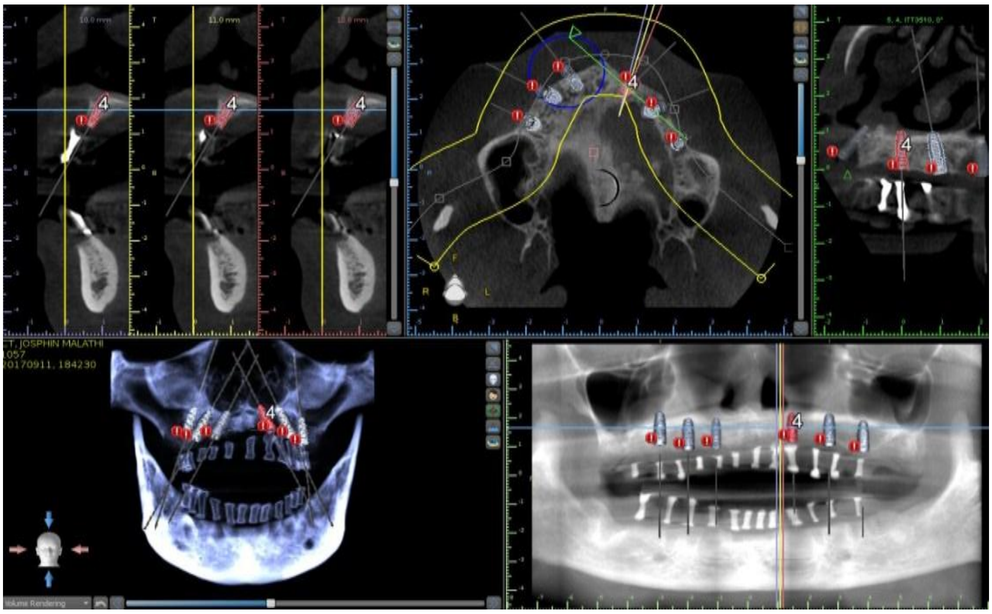
VIRTUAL PLANNING OF IMPLANT IN THE REGION OF 24.



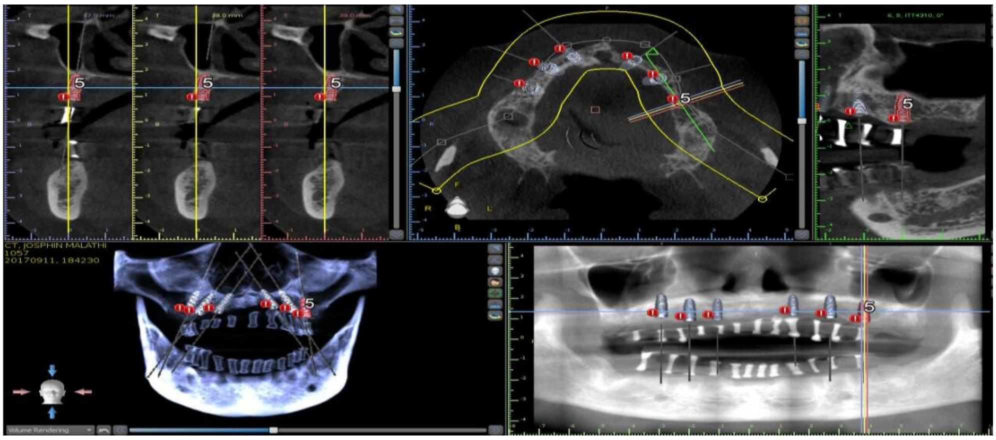
VRITUAL PLANNING OF IMPLANT IN THE REGION OF 14.



VRITUAL PLANNING OF IMPLANT IN THE REGION OF 22.

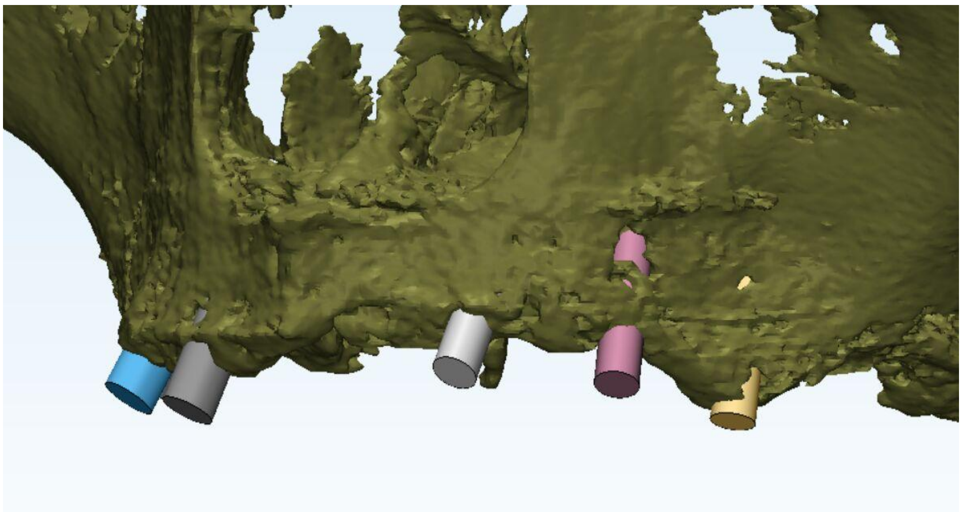


VRITUAL PLANNING OF IMPLANT IN THE REGION OF 26.

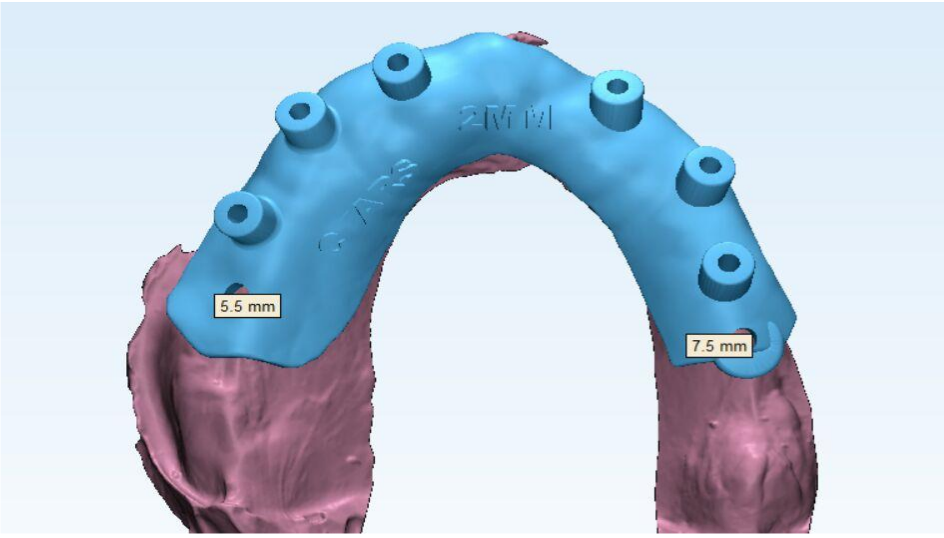


VIRTUAL PLANNING OF IMPLANT POSITION OF RIGHT MAXILLLARY REGION.

VIRTUAL PLANNING OF IMPLANT POSITION OF LEFT MAXILLLARY REGION.



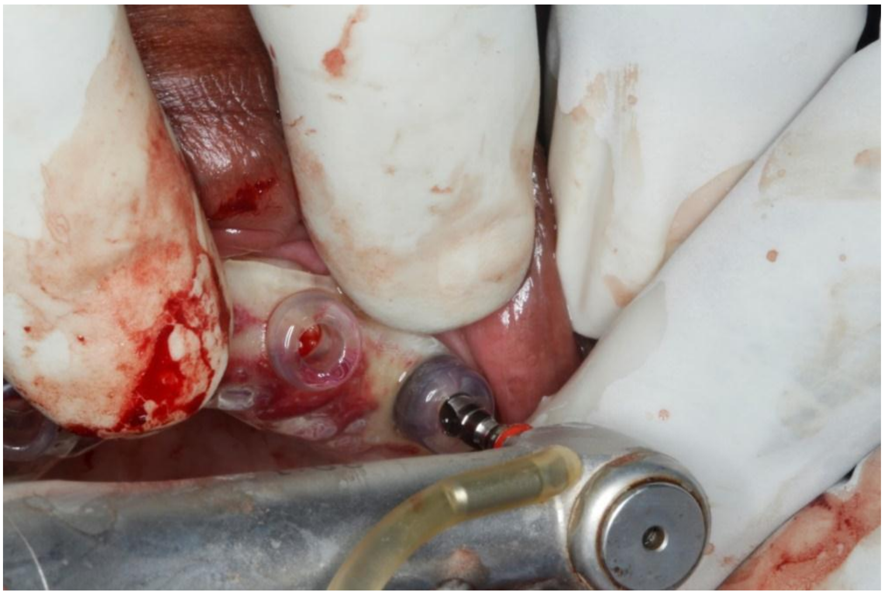
VIRTUAL 3D SURGICAL GUIDE.



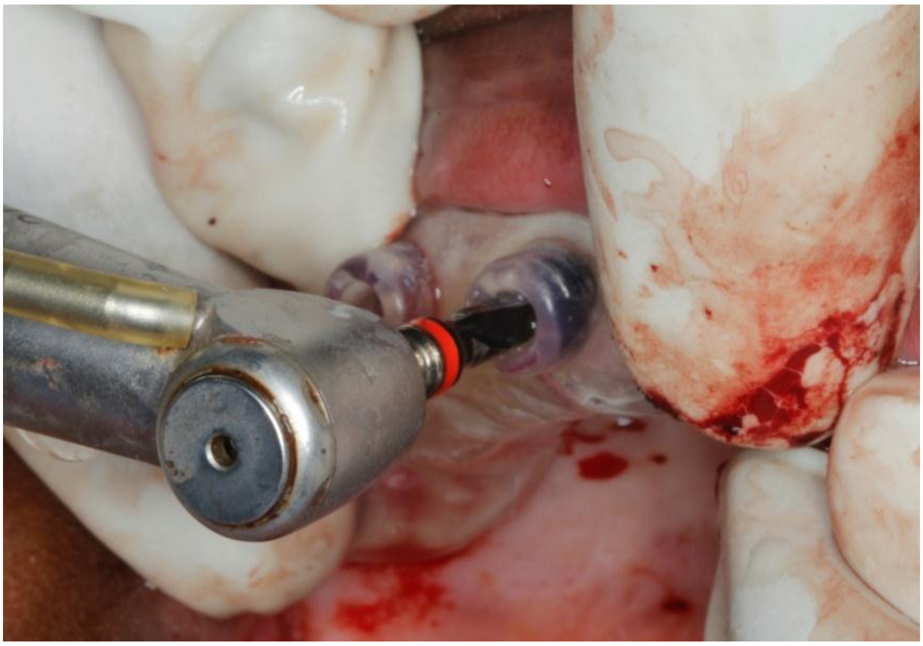
DIGITALLY PLANNED 3D PRINTED SURGICAL STENT FOR MAXILA.

EDENTULOUS MAXILLA.

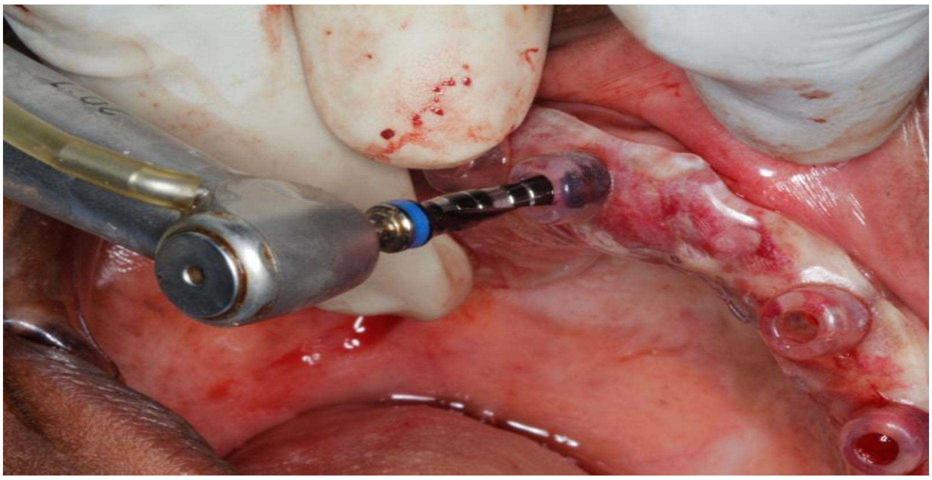
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL IN THE REGION OF 24.



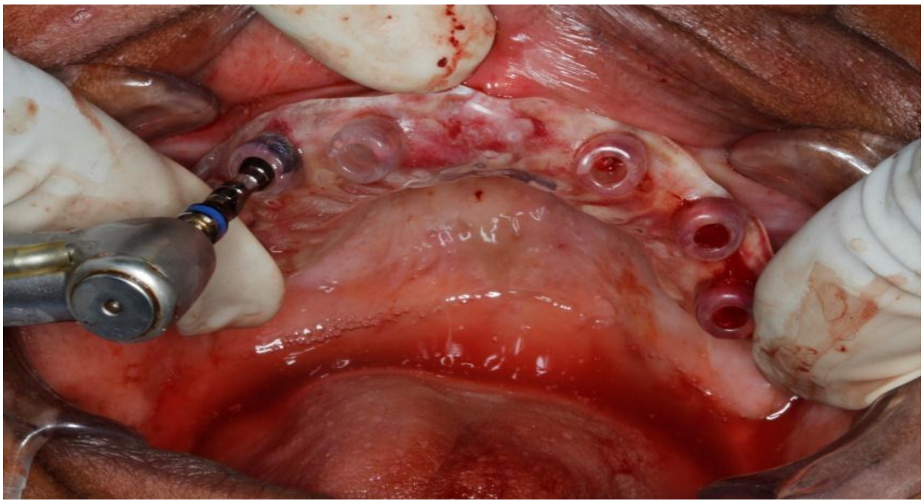
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 2.8MM DRILL IN THE REGION OF 12 .



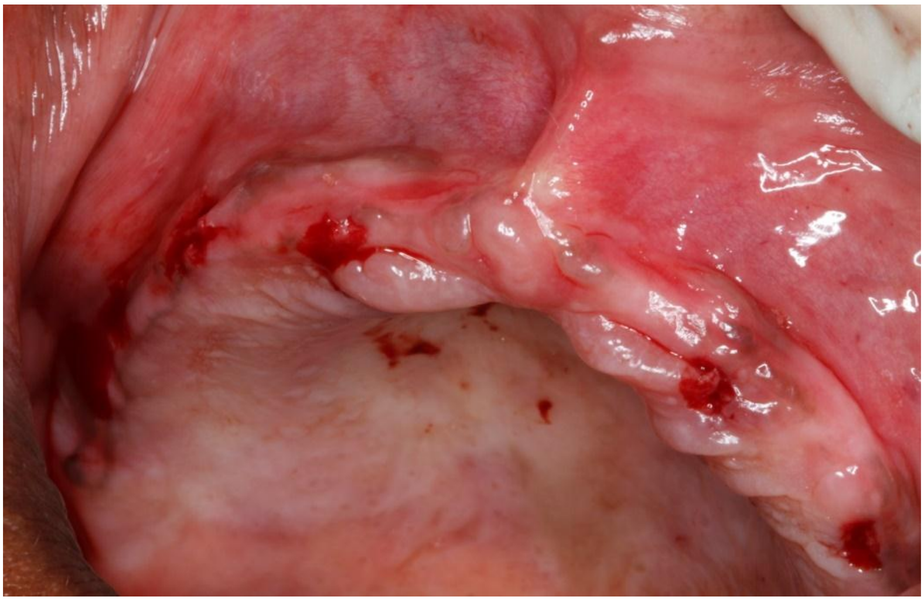
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.2MM DRIL IN THE REGION OF 22.



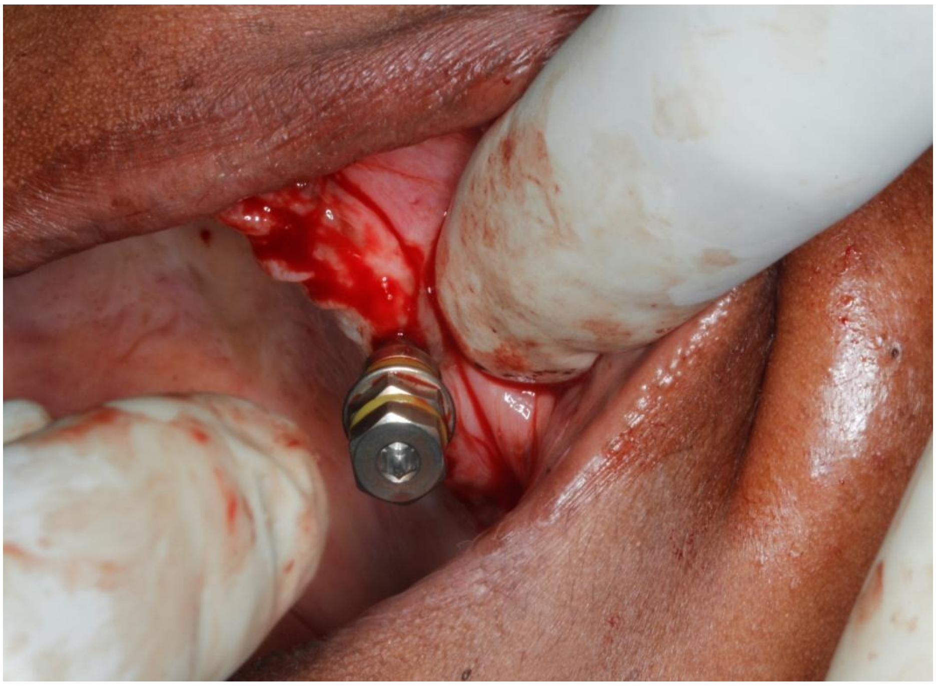
SEQUENTIAL IMPLANT OSTEOTOMY PREPARATION USING 3.2MM DRILL IN THE REGION OF 14.



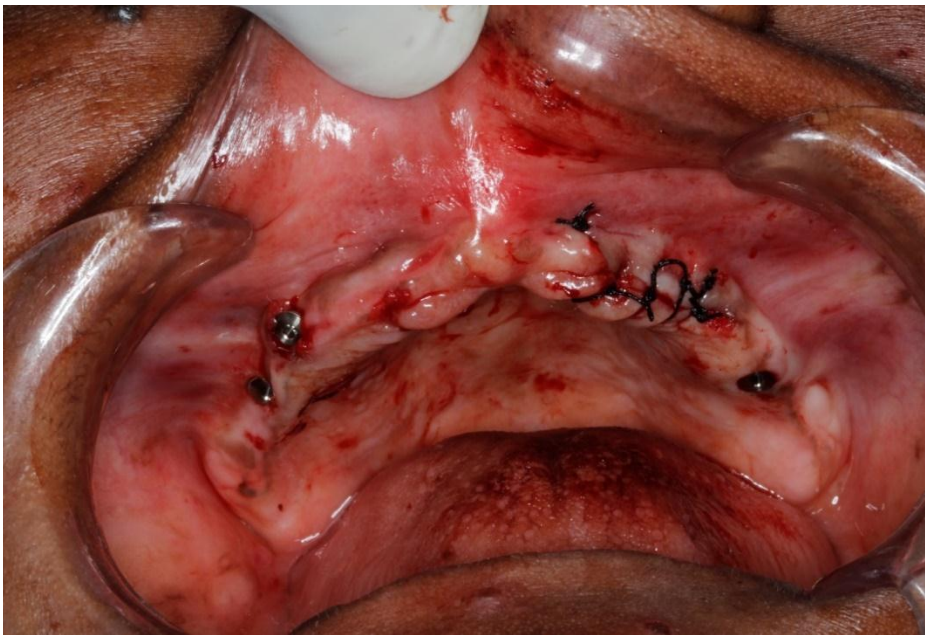
SURGICAL IMPLANT OSTEOTOMY SITES PREPRED USING 3D SURGICAL GUIDE.



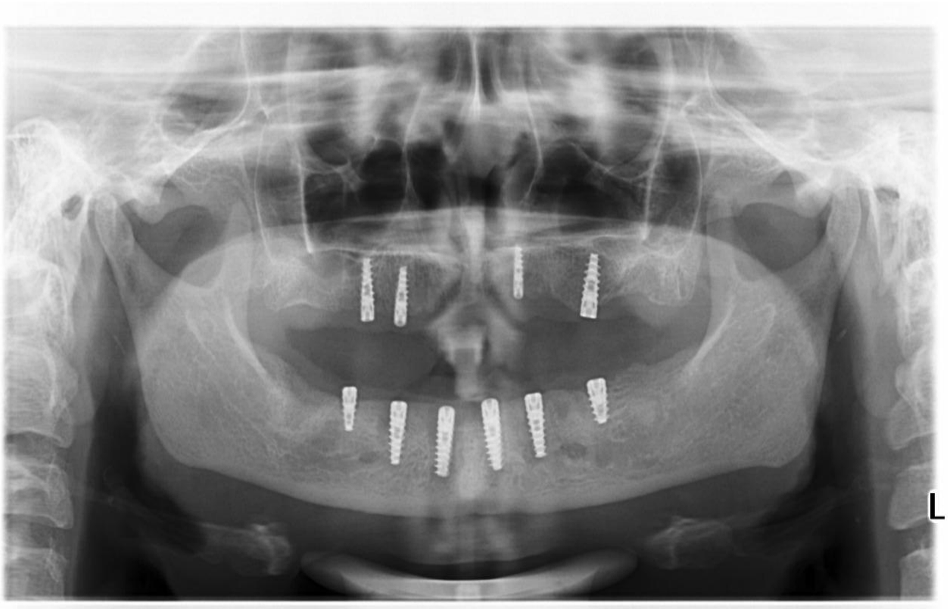
PLACEMENT OF IMPLANTS WITH MOUNT.



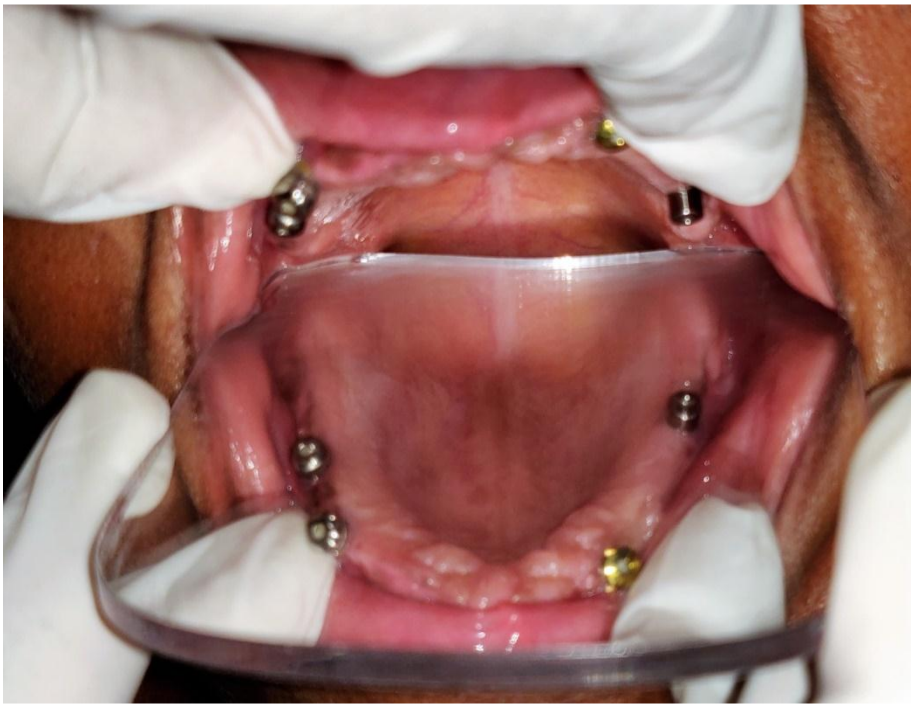
IN LEFT MAXILLLARY ANTERIOR ONE IMPLANT HAD BEEN PLACED FREE HANDEDLY ADJACENT TO THE PLANNED DRILLING SITE DUE TO THE OVER PREPARATION AND SUTURES PLACED.



POST OPERATIVE OPG.



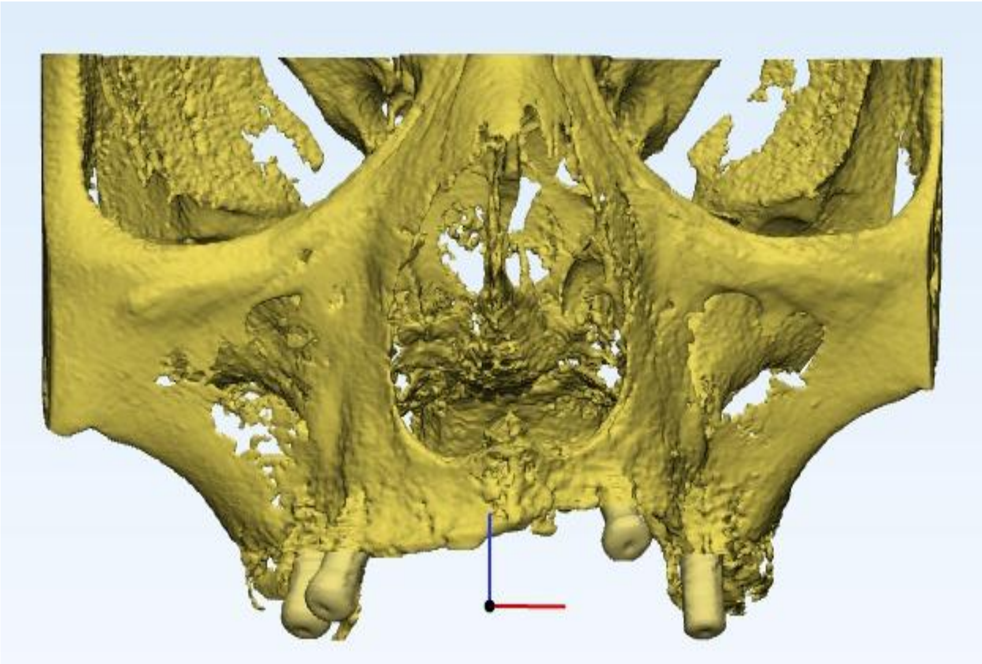
HEALING ABUTMENT PLACED AFTER 6 MONTHS.



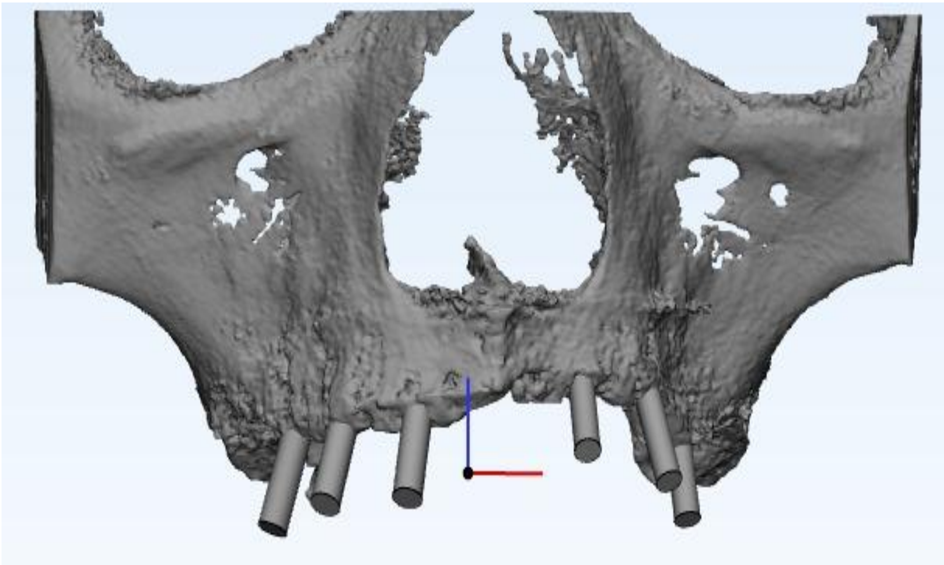
HYBRID DENTURE PLACED IN MAXILLA AND MANDIBLE.

SUPERIMPOSITION OF VIRTUAL PLANNING AND POSTOPERATIVE CBCT IN 3D

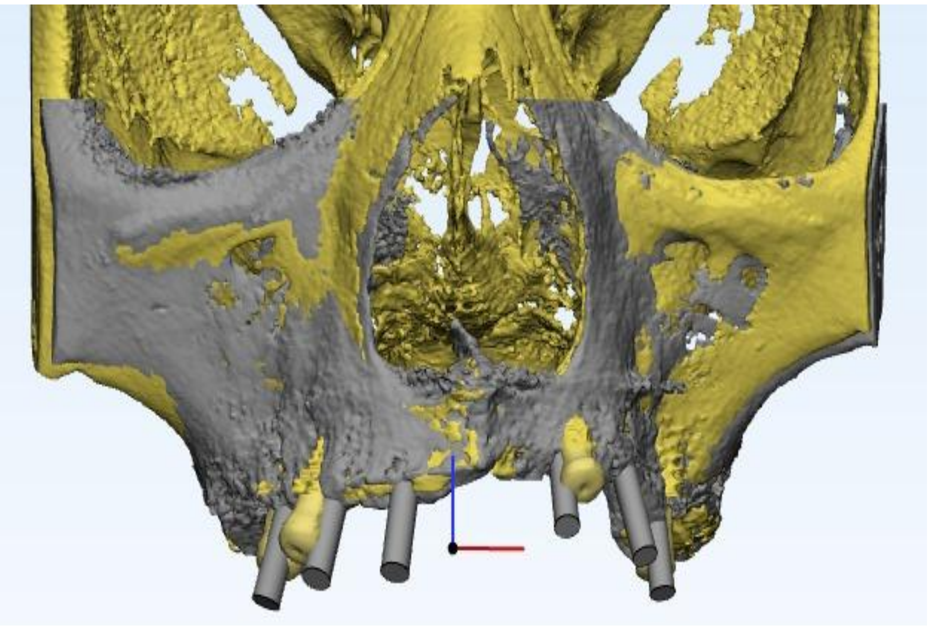
ACTUAL PLACEMENT OF IMPLANTS IN MAXILLA.



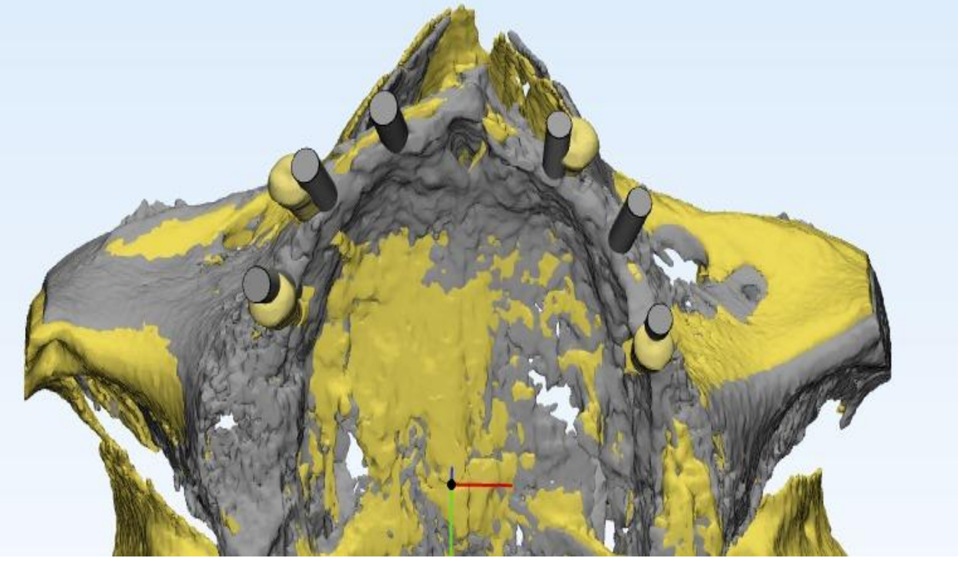
VIRTUAL PLANNING OF IMPLANTS IN MAXILLA.



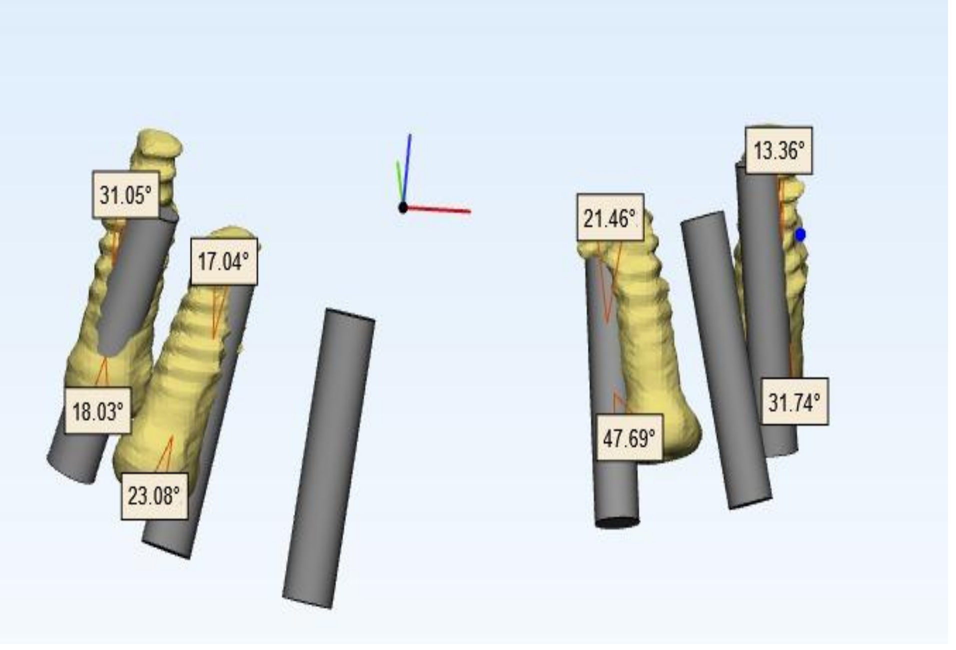
SUPERIMPOSING OF THE PLACED IMPLANTS OVER THE VIRTUAL PLANNING.



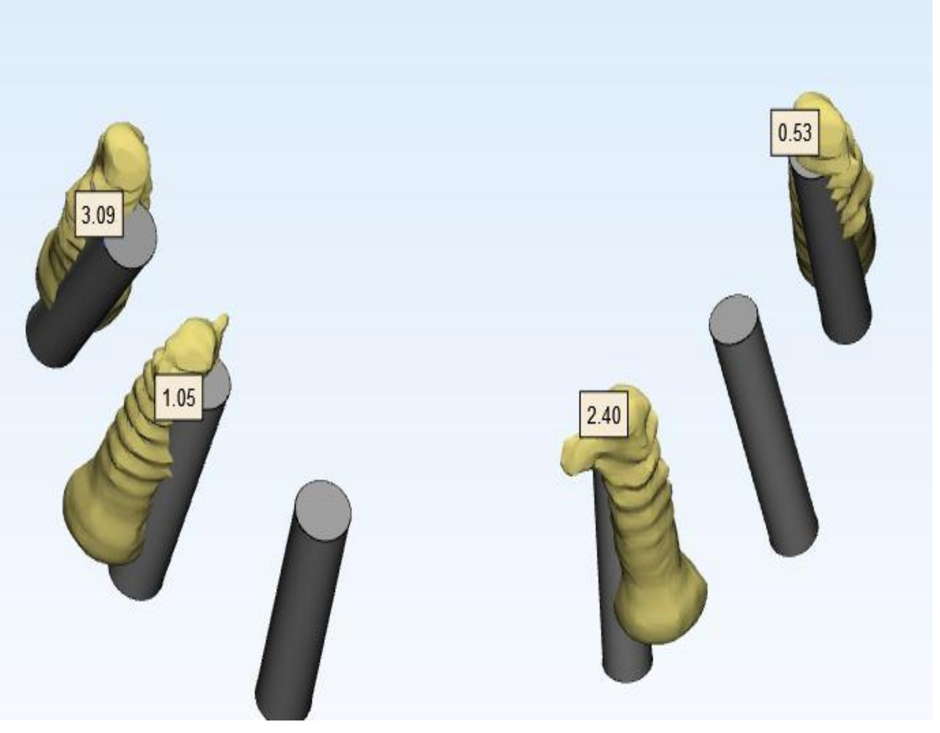
SUPERIMPOSING OF THE PLACED IMPLANTS OVER THE VIRTUAL PLANNING.



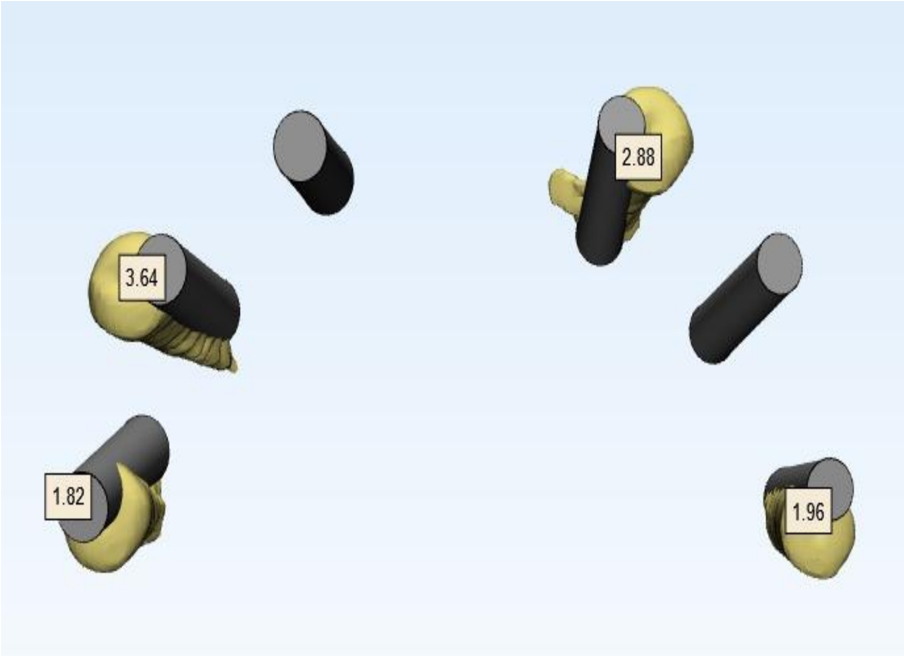
ANGULATION OF THE IMPLANTS AT THE CREST AND APEX(IN DEGREES).



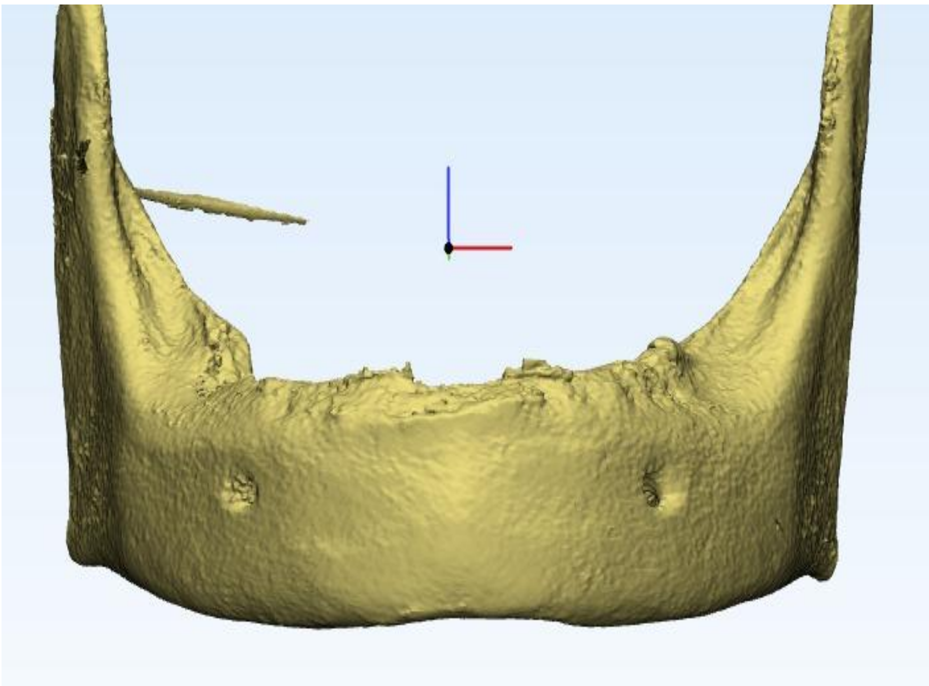
DEVIATION OF THE IMPLANTS AT APEX(IN MM).



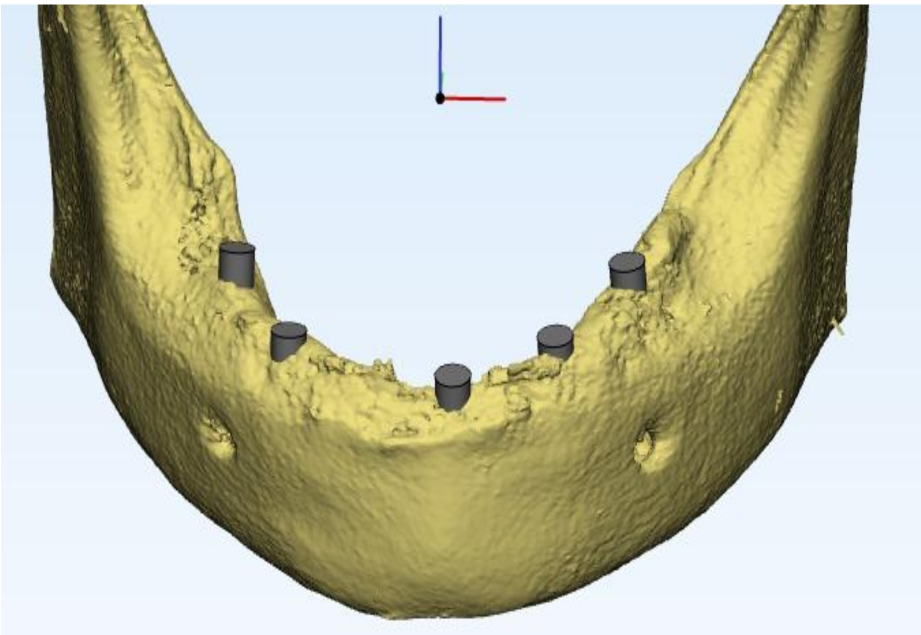
DEVIATION OF THE IMPLANTS AT CREST(IN MM).



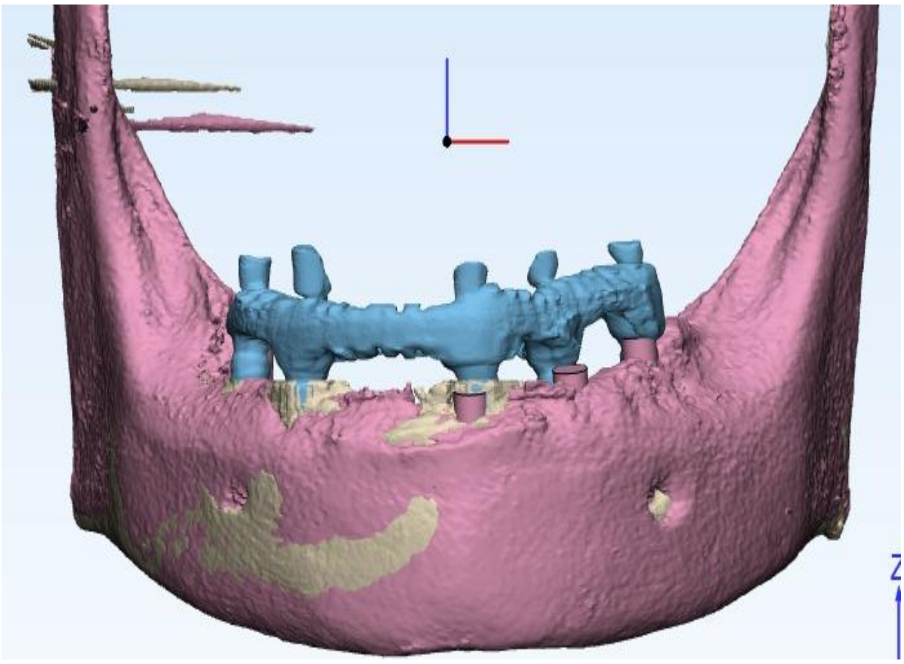
3D RECONSTRUCTION OF EDENTULOUS MANDIBLE.



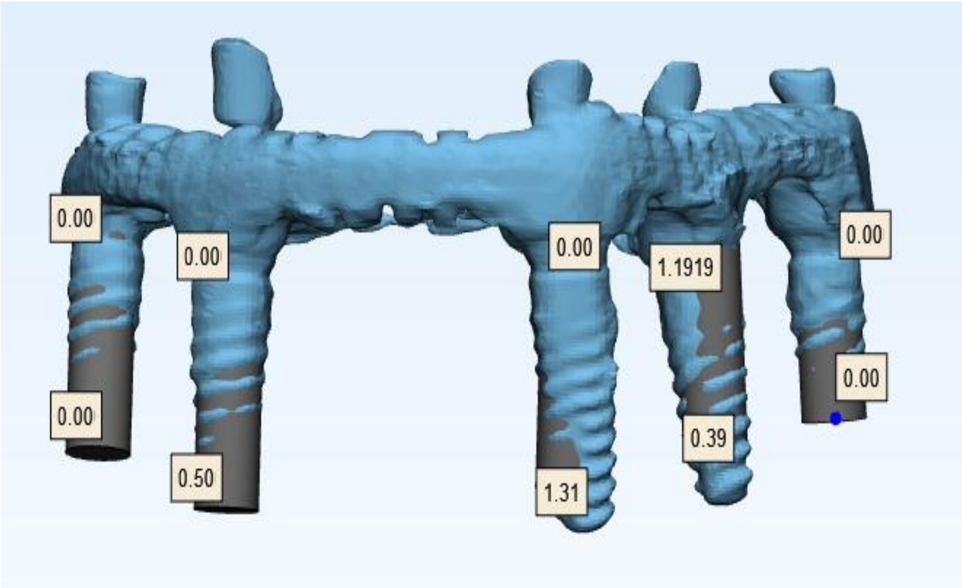
VIRTUAL PLANNING OF IMPLANTS.



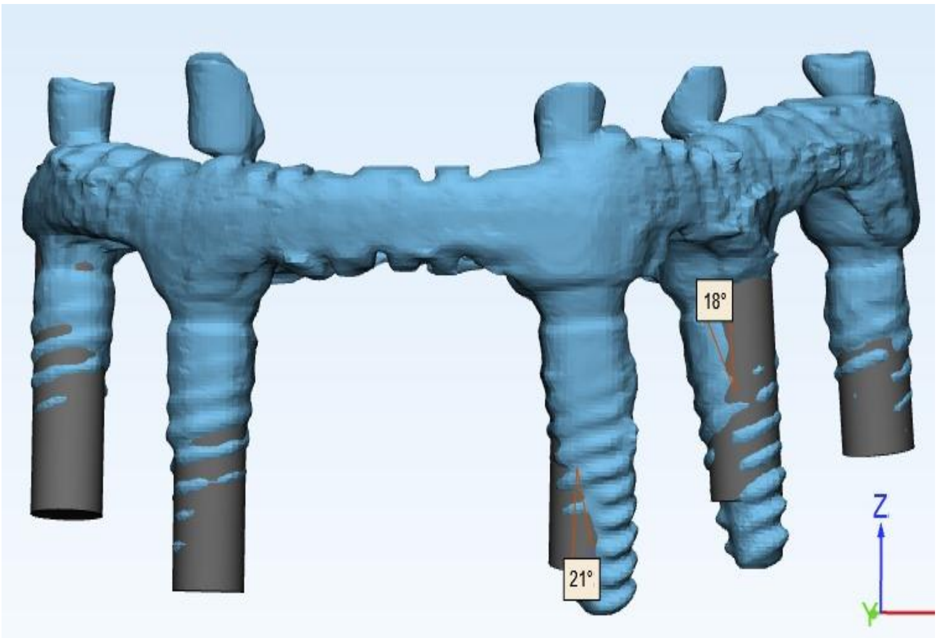
ACTUAL PLACEMENT OF IMPLANTS AFTER FIXATION OF HYBRID DENTURES.



DEVIATIONS OF THE IMPLANTS AT CREST AND APEX(IN MM).



ANGULATION OF THE IMPLANTS(IN DEGREES).



Results

RESULTS

The present prospective, clinical study was designed to evaluate the accuracy of angulation of the implants placed using digital surgical guides by superimposing the cone beam computed tomography scan of actual implant that was placed on the patient over virtually planned implant position. This study was undertaken on 4 patients, who reported to the Outpatient Department, Department of Oral and Maxillofacial Surgery, Ragas Dental College, Uthandi, Chennai, for replacement of missing teeth with dental implant based restorations. Implants were placed using 3D printed surgical guides.

Preoperative CBCT scans were taken before the surgery to perform virtual planning and according to that 15 implants were placed in four patients (10 implants were placed in one female patient, 2 implants in another female patients, 2 implants in one male patient,1 implant in other male patient). Of the above, 1 implant failed in mandible and 1 implant had been placed using free hand in maxilla. Post-operative CBCT scan were taken after six months of surgery to obtain the angulation and deviation of the implants placed using 3D printed surgical guides.

ANGULATION AT CREST

The angulation of the placed implants at the crestal level was evaluated 6 months post implant placement and was compared with the pre-operative CBCT virtual planning with baseline value kept at zero degree.

The crestal change in angulation was zero degrees for 9 implants and for the remaining 4 implants the crestal angulation was 18, 18.03, 23.08 and 31.74 degrees.(TABLE 1)

The mean value for the angulation at crest was 6.9885 degrees and the standard deviation was 11.38088 degrees. (TABLE 2)

ANGULATION AT APEX

The angulation of the placed implants at the apex was evaluated 6 months post implant placement and was compared with the pre-operative CBCT virtual planning with baseline value kept at zero degree.

The apical change in angulation was zero degrees for 9 implants and for the remaining 4 implants the apical angulation was 19.69, 21, 31.05 and 17.04 degrees. (TABLE 1)

The mean value for the angulation at apex was 6.8292 and the standard deviation was 11.09377 (TABLE 2)

DEVIATION AT CREST

The deviation of the placed implants at the crestal level was evaluated 6 months post implant placement and was compared with the pre-operative CBCT virtual planning with baseline value kept at zero mm.

The crestal chage in deviation was zero mm for 9 implants and for the remaining 4 implants the crestal deviation was 1.19,1.82,3.64,1.96 mm.(TABLE 1)

The mean value for the deviation at crest was 0.6623mm and the standard deviation was 1.15892mm.(TABLE 2)

DEVIATION AT APEX

The deviation of the placed implants at the apical level was evaluated 6 months post implant placement and was compared with the pre-operative CBCT virtual planning with baseline value kept at zero mm.

The apical change in deviation was zero mm for 6 implants and for the remaining 7 implants the apical deviation was 1.1, 0.5, 1.31, 0.39, 3.09, 1.05, 0.53 mm. (TABLE 1)

The mean value for the deviation at apex was 0.6131mm and the standard deviation was 0.8831mm.(TABLE 2)

Tables and Graphs

TABLE -1 Deviation of implants at crest and apex in angulation (°) and distance (mm)

S.No	Baseline Crest	Baseline Apex	After 6 Months (deviation) crest in mm	After 6 Months (deviation) apex in mm	After 6 Months (Angulation) crest in Degree	After 6 Months (Angulation) Apex in Degree
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	1.1	0	19.69
4	0	0	0	0	0	0
5	0	0	0	0.5	0	0
6	0	0	0	1.31	0	21
7	0	0	1.19	0.39	18	0
8	0	0	0	0	0	0
9	0	0	1.82	3.09	18.03	31.05
10	0	0	3.64	1.05	23.08	17.04
11	0	0	1.96	0.53	31.74	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0

TABLE - 2 Cumulative assessment of deviation of implant in degrees, mm, crest and apex

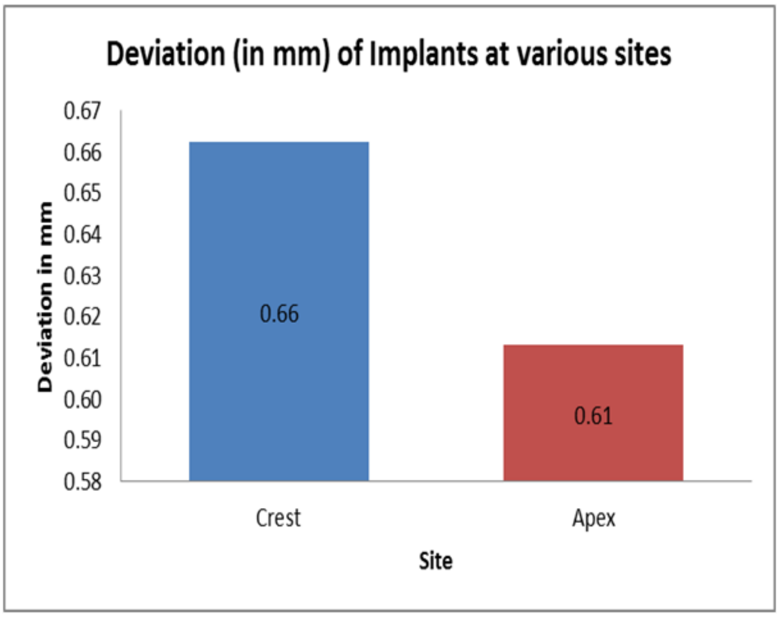
Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation
After 6 Months (deviation)crest in mm	0.00	3.64	.6623	1.15892
After 6 Months(deviation) apex in mm	0.00	3.09	.6131	.88381
After 6 Months(Angulation)crest in Degree	0.00	31.74	6.9885	11.38088
After 6 Months(Angulation) Apex in Degree	0.00	31.05	6.8292	11.09377

GRAPH 1

DEVIATION (IN MM) OF IMPLANTS AT VARIOUS SITES

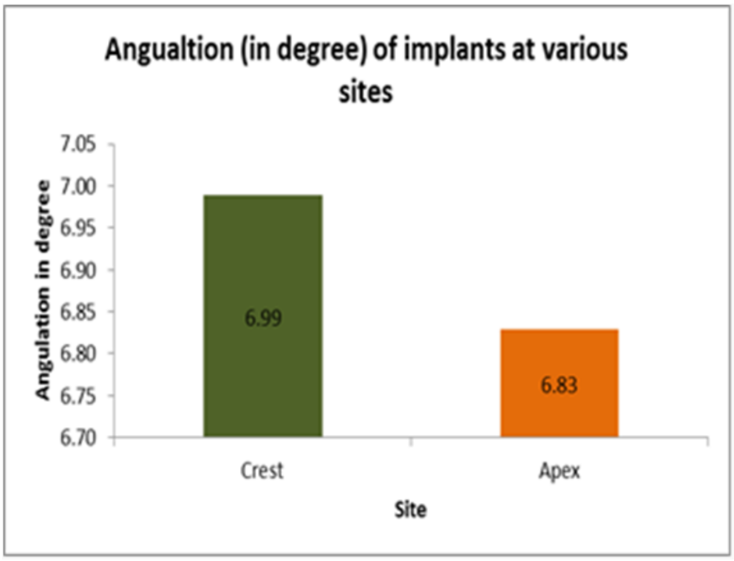
Site	Deviation(in mm)
Apex	0.61



GRAPH 2

ANGUALTION (IN DEGREE) OF IMPLANTS AT VARIOUS SITES

Site	Angulation(in degrees)
Crest	6.99
Apex	6.83



Discussion

DISCUSSION

Dental implants have been considered the standard care for rehabilitation of missing teeth as they provide better long term results than the conventional teeth replacement options. A dental implant is actually a replacement for the root or roots of a tooth. Similar to tooth roots, dental implants are secured in the jawbone and are not visible once surgically placed. They are used to secure crowns (the parts of teeth seen in the mouth), bridgework or dentures by a variety of means. They are made of titanium, which is lightweight, strong and biocompatible. Titanium and titanium alloys are the most widely used metals in both dental and other bone implants, such as orthopedic joint replacements. Dental implants have the highest success rate of any implanted surgical device. Dental implant restorations are most like natural teeth in feel, look and function. Since the implants are surgically placed in jawbone, they integrate with the bone and act like real teeth. Dental implants preserve the jawbone and prevent bone from resorbing (disappearing) over time.

Ancient dental implants have been traced back to around 600 AD, when tooth-like pieces of shell were hammered into the jaw of a Mayan woman. Dental implants are the only dental restoration option that preserves natural bone, actually helping to stimulate bone growth. Branemark's first patient had severe deformities of the jaw and chin, congenitally missing teeth and misaligned teeth. Four implants were inserted into the mandible. These implants integrated within a period of six months and remained in place for the next 40 years He found this discovery accidentally in 1952 when he was studying blood flow in rabbit femurs by placing titanium chambers in their bone; over time the chamber became firmly affixed to the bone and could not be removed. The bone actually bonded to the titanium surface. Infact if a fracture occurred, it always occurred between bone and bone, never between the bone and the implant. After this chance observation, Branemark developed a new concept of osseointegration and the advent of osseointegration has rapidly led to use of dental implants over recent years. He defined the term osseointegration as “A direct structural and functional connection between ordered, living bone, and the surface of a load carrying implant”.

Angulation of the implant is a crucial factor that has to be considered while placing an implant. If the angulation is inappropriate the implant may damage the neighbouring vital anatomic structures and the root to the adjacent teeth. Improper angulation leads to lack of esthetic replacement of prosthetic crown or bridge. In addition it may contribute to gingival recession as well.

Conventional surgical templates are fabricated on dental casts, which is a rigid, non-functional surface without the knowledge of underlying soft tissue resiliency and bone topography. Anatomical landmarks are not precisely located and the approach is always two dimensional. Hence, there are high chances of malpositioning the implants during placement[28]. The success of the final outcome always depends on clinical skill and alertness. It requires more chair time, leads to stress on the dentist and patient. Although conventional surgical templates will allow the placement of implant guiding, they do not provide exact 3D guidance. To overcome the limitations associated with conventional radiographic surgical template, computer generated surgical template have been evolved. A computer generated surgical guide provides a link between our treatment plan and the actual surgery by transferring the simulated plan accurately to surgical site. This surgical guide is made using stereolithography process and is custom manufactured for each patient.

Stereolithography, a rapid prototyping technology, a newer outcome in dentistry allows the fabrication of surgical guides from 3D computer generated models for precise placement of the implants. The surgical templates fabricated by this technology are pre-programmed with individual depth, angulations, mesio-distal and labiolingual positioning of the implant.

Steriolithographic templates allow practitioners to virtually view the implant site and plan location, angle, depth, and diameter of virtual implants, which are superimposed on the 3D data. It can assist the practitioner in avoiding damage to anatomic structures, as well as limiting fenestration and dehiscence of the alveolar ridge at potential implant sites.

Corina Marilena Cristache et al (2017) stated that the surgical template with sleeve incorporated, designed to reduce mechanical tolerance of surgical instruments, used in their study has proved high accuracy for dental implants insertion[35].

Casetta.M et al (2013) concluded that the results of his study indicated best accuracy of the single-type guide using a bone or tooth support. The multiple-type guide recorded the best accurate data when the mucosa support was considered comparing either a fixed and a not-fixed single-type guide[36].

Al Harbi S.A et al (2009) stated that when measured using the CMM, the stereolithographic surgical template was sufficiently accurate in transferring the planned implant position to the surgical field relative to the implant angulations and point of entrance[37].

In our study in case 1, no changes were recorded in the angulation and deviation at the crest and apex of the implant. In case 2, two implants were placed in left and right mandibular posterior region. In the right side, there were no changes. In the left side, there was a deviation only at the apical region and the deviation was 1.1 mm and the angulation was 19.69 degrees. In case 3, ten implants were placed (4 in maxilla and 6 in mandible).The deviational changes at crest in the maxilla for 3 implants were 3.64mm,1.82mm and 1.96mm and in mandible there were no deviational changes for 3 implants and in one implant it was 1.19mm.The deviational change at apex in the maxilla for 3 implants were 1.05mm,3.09mm and 0.53mm.In mandible there were no deviational changes at apex for 2 implants and for the remaining 3 implants the deviational changes were 0.5mm,1.31mm and 0.39mm. the angulational changes at crest for 3 implants in maxilla were 31.05 degrees, 72.04 degrees, 13.36 degrees and in mandible the angulational changes at apex for 4 implants is 0 degrees & for 1 implant is 18 degrees. The angulation changes at apex for 3 implants in maxilla were 18.03 degrees, 23.08 degrees and 31.74 degrees & the angulation changes at apex in mandible for 4 implants were 0 degrees and for one implant was 21 degrees.

In case 4, two implants were placed in the left posterior mandibular region and there were no changes in the angulation and deviation.

Even though the results were clinically satisfactory, mild changes in position had occurred in implants which were placed using stereolithographic surgical guide. But all those changes occurred in one particular female patients who underwent full mouth extraction due to aggressive periodontitis followed by alveoloplasty. After the healing of gingival tissues implants were placed both in the maxillary and mandibular region. Totally 10 implants were placed out of which 4 in maxillary region, 6 in mandibular region. In the maxillary region, there were changes in the angulation and deviation at both the crest and apex. In the mandibular region there were changes in the angulation and deviation at crestal region for one implant and at the apical region for one implant.

The deviational changes crest in the maxilla for 3 implants were 3.64mm,1.82mm and 1.96mm and in mandible there were no deviational changes for 3 implants and in one implant it was 1.19mm.The deviational change at apex in the maxilla for 3 implants were 1.05mm,3.09mm and 0.53mm.In mandible there were no deviational changes at apex for 2 implants and for the remaining 3 implants the deviational changes were 0.5mm,1.31mm and 0.39mm. the angulational changes at crest for 3 implants in maxilla were 31.05 degrees, 72.04 degrees, 13.36 degrees and in mandible the angulational changes at apex for 4 implants is 0 degrees & for 1 implant is 18 degrees. The angulation changes at apex for 3 implants in maxilla were 18.03 degrees, 23.08 degrees and 31.74 degrees & the angulation changes at apex in mandible for 4 implants were 0 degrees and for one implant was 21 degrees.

The changes in angulation and deviation of the implant could be due to the improper placement of surgical guides. Giovanni et al (2005) stated that the computer aided rapid prototyping of surgical guide technique requires improvement to provide better stability of the guide during the surgery, in case of unilateral bone supported and non tooth-supported guides [10].

In this patient, surgical guides were placed on the edentulous maxillary region with the support of anchoring pins in the left and right posterior region as it was a non tooth-supported guide the position and stability would have altered during the drilling and placement of implants.

In addition, the changes in position of the implant could be influenced by the diameter and length of the guide sleeve of the surgical guide and the distance between the undersurface of the template and the targeted alveolar crest which leads to intrinsic error.

Casetta et al (2008) suggested that potential mechanical error is the most significant factor than the other variables that would affect the accuracy of implant placement in spite of improper transfer of virtual planning to surgical field, there could be errors in implant placement. In our study, the mean deviation at the crest was 0.6623mm and at apex was 0.6131mm[38].

Varcauyssen et al (2008) presented a paper to review the literature on the use of CT scan based planning for oral rehabilitation and it is transferred to the surgical field by means of a surgical guide. He also stated that maximal deviation could be 1-1.5 mm[39].

Bone plays a major role in osseointegration and implant stability. Implants primary stability depends on these factors:

- Bone quality,
- Mechanical shape of the fixture placed in the bone,
- The surgical protocol which was followed for insertion of fixture has been inserted[40].

Yoon et al (2011) stated that the bone quality and surgical technique have an influence on the implant's primary stability and resonance frequency has a positive relation with the density of implant fixture and surrounding bone. The above factors cannot be assessed in conventional templates[40].

This specific patient had a deficient bone in her maxillary region, she presented with 3 mm width, especially in the anteriors. In that case, flap surgery could be preferred over flapless technique. Elevating a flap leads to proper visualization of bone. For this patient, in the maxillary anterior region the implant had been removed due to the over-preparation of implant site using surgical guide. So we placed the implant near the prepared drilling site with free-hands. Therefore, the recommended technique for these type of cases would be flap elevation and bone augumentation.

Romero Ruiz et al (2015) stated that the main obstacle of flapless surgery was the fact of limited visibility of the drilling and during implant placement, so the risk of improper angulation directions or damaging neighbour structures is higher than with the conventional technique[30].

In this patient, there were changes in two implants one at crest and the other at apex. The deviations were less than 1.5mm. One implant had been removed post-operatively during the placement of healing abutment due to peri-implantitis which occurred at that site.

Venkatesh et al (2017) stated both the advantages and limitations of CBCT 2D imaging has assisted dentistry effectively and is bound to do so in the near future. He also stated that CBCT imaging surpasses obstacles of 2D imaging, offering practitioners with high quality, sub-millimeter resolution images, with short scanning time and low radiation dose. Since this equipment has become accompaniment of the dentist, dependence upon practice-based guess-estimations will be replaced, benefiting both patient and dentist. In our study we used CBCT instead of CT because it has many advantages compared to CT. High radiation dose, availability, cost, poor resolution, longer scanning time and difficulty in interpretation have led to restricted use of CT in dentistry[41].

In our study we used gutta percha as radiographic markers as it provides less shattering of the image, produces high radio-opacity, ease of availability, low cost.

In our study we noticed that implants were parallelly placed, patients had minimal swelling and minimal pain. The rate of healing was fast, the placement of sutures were not required as it was a flapless surgery. Although the guided surgery increases the number of steps compared to freehand placement operating time was short and minimal bleeding was encountered when compared to free handed surgery. We found out that very minimal changes occurred in the angulation and deviation & the mean value of changes in the angulation at crest was 6.9885 degrees and at apex was 6.8292 degrees. The standard deviation for angulation at crest was 11.38088 degrees and at apex was 11.09377 degrees. The changes in the mean value of the deviation at crest was 0.6623mm and the standard deviation was 1.15892mm. The changes in the deviation of the mean value at apex was 0.6131mm and at the standard deviation was 0.88381mm.

G.devico et al (2016) stated that computer aided surgery allows to select the implant position in depth,inclination and mesiodistal distance between natural teeth and or other implants enabling a very safe and predictable rehabilitation compared with conventional surgery[42].

Kunal Lal, DDS, MS, George S. White, DDS Dennis N. Morea, DDS and Robert F. Wright, DDS (2006) presented an article about the use of stereolithographic templates for Surgical and Prosthodontic Implant Planning and Placement. They concluded that the stereolithographic templates could be used in completely as well as partially edentulous situations. The templates could be entirely supported either by soft tissue, bone, or remaining teeth. The cost associated was higher than with conventional templates, but in more complex, fully edentulous cases, the benefit could justify the additional expense. The use of this approach could make the goal of ideal surgical and prosthodontic implant placement a distinct possibility. Considering the possible benefits and implications of achieving this goal, it would be prudent to direct further clinical research endeavors toward validating the accuracy and effectiveness of the system[14].

David R. Burns, D.M.D., Donald G. Crabtree, D.D.S., and Dewey H. Bell, D.D.S. (1988) described a technique for fabrication of a surgical guide that gives the surgeon the appropriate location and angulation of the submerged implant relative to the opposing dentition. Presurgical planning for submerged implant location and angulation within bone relative to the opposing occlusion was important for the restorative dentist. This information would be accurately communicated to the surgeon by using a surgical template[1].

Kevin C. Kopp, BS, DDS, Alyson H. Koslow, BS, DDS, and Omar S. Abdo, BDS, MSc (2003) presented an article about precise dental implant placement. A barium-coated template with external guide wires used in conjunction with a computed tomography scan and interactive software may provide superior presurgical diagnostics, treatment planning, and prosthetically directed implant placement. Measurements predetermined on the computed tomography scan could be transferred accurately to the diagnostic/surgical template by use of a precision milled cylinder placed into the template at the proper angulation and linear dimensions. The diagnostic/surgical template indicates the optimal position for implant placement, thus establishing greater clinical confidence when placing implants. They concluded that the location of implant placement was often critical to the success or failure of a particular restoration. .Placing a wire buccally allows for the marker to remain intact and not be obliterated when preparing the template for the surgical phase. With this method, the buccolingual and mesiodistal positions could be maintained throughout the surgery. This was accomplished by affixing an external guide wire that remains with the template from diagnostic CT imaging to surgical placement of the implant. The use of a diagnostic/surgical template may allow predictable implant placement and was simple and inexpensive to fabricate[6].

The advantages of digitally planned 3D printed surgical stent were more precise placement of implants, minimal operating time, decreased risk of damaging anatomical structures, minimally invasive, less postoperative pain and swelling and it is easy of implant placement for beginners.

The disadvantages of digitally planned 3D printed surgical stent were high cost, need for elaborate software and trained technicians to plan and print digital implant guide. An accurate reproduction of soft tissue contour digitally can be a challenge. If virtual planning is inaccurate and if the implants were placed based on 3D digital guide neighbouring vital anatomical structures can be damaged. Although, density can be estimated in Hounsfield unit, the exact quality of bone cannot be accurately evaluated. However, surgical guides give an indication pertaining to the implant angulation alone.

Summary and Conclusion

SUMMARY AND CONCLUSION

Thus from the results of the study we would like to conclude that the placement of dental implants using digitally planned surgical guides is within clinically acceptable limits. It further ensures minimal or virtually nil damage to the relevant anatomical structures and makes implant placement less difficult for beginners.

We believe, the usage of digitally planned surgical guides for dental implants would be routinely employed in routine dental implant practice in future, if the cost involved in virtual planning and 3D printing is reduced. However a study involving larger sample size would give us more reliable results in this regard.

Bibliography

BIBLIOGRAPHY

1. **Al Burns D.R., Crabtree D.G., Bell D.H.** Template for positioning and angulation of intraosseous implants *.The Journal of Prosthetic Dentistry(1988)*, 60 (4) , pp. 479-483.
2. **Pesun I.J., Gardner F.M.** Fabrication of a guide for radiographic evaluation and surgical placement of implants. The Journal of Prosthetic Dentistry(1995), 73 (6) , pp. 548-552.
3. **Naitoh M, Ariji E, Okumura S, Ohsaki C, Kurita K, Ishigami T. Can Munetaka Naitoh.** Implants be correctly angulated based on surgical templates used for osseointegrated dental implants?. Clin Oral Impl Res 2000: 11: 409–414.
4. **Roger A. Solow, DDS** Simplified radiographic-surgical template for placement of multiple, parallel implants. A radiographic-surgical template can facilitate consultation with a surgeon and patient when implant-supported restorations are planned. A template that provides radiographic evaluation of the implant site and precise or modified surgical placement is presented. (J Prosthet Dent 2001;85:26-9).
5. **Kıvan Aka, DDS, PhD, Haldun I plikioglu, DDS, PhD, and Murat C. ehreli, DDS, PhD** . A surgical guide for accurate mesiodistal paralleling of implants in the posterior edentulous mandible . (J Prosthet Dent 2002;87:233-5).

6. **Kevin C. Kopp, BS, DDS, Alyson H. Koslow, BS, DDS, and Omar S. Abdo, BDS, MSc** Predictable implant placement with a diagnostic/surgical template and advanced radiographic imaging. (J Prosthet Dent 2003;89:611-5).
7. **Rocci A, Martignoni M, Gottlow J.** Immediate loading in the maxilla using flapless surgery, implants placed in predetermined positions, and prefabricated provisional restorations: a retrospective 3-year clinical study. Clin Implant Dent Relat Res. 2003;5 Suppl 1:29-36.
8. **Mohammed Zaheer Kola, Altaf H Shah, Hesham S Khalil, Ahmed Mahmoud Rabah, Nehad Mohammed H Harby,Seham Ali Sabra,and Deepti Raghav**Surgical Templates for Dental Implant Positioning; Current Knowledge and Clinical Perspectives. Niger J Surg. 2015 Jan-Jun; 21(1): 1–5.
9. **Brief J, Edinger D, Hassfeld S, Eggers G.** Accuracy of image-guided implantology. Clin. Oral Impl. Res. 16, 2005; 495–501.
10. **Di Giacomo GA, Cury PR, de Araujo NS, Sendyk WR, Sendyk CL.** Clinical application of stereolithographic surgical guides for implant placement: preliminary results. J Periodontol. 2005 Apr;76(4):503-7.
11. **Alan.L.Rosenfield,George.A.Mandelaris,Phillipe.b.Tardieu.**Prosthetically directed implants using computer software to ensure precise placement and predictable prosthetic outcomes.Int J Periodontics Restorative Dent 2006;26:215-21.

12. **Widmann G, Bale RJ** .Accuracy in computer-aided implant surgery--a review. Int J Oral Maxillofac Implants. 2006 Mar-Apr;21(2):305-13.

13. **Dov M. Almog, B. W. Benson, L. Wolfgang, N. L. Frederiksen, S. L. Brooks.**Computerized Tomography–based Imaging and Surgical Guidance in Oral Implantology, Journal of Oral Implantology. 2006;32(1):14-18.

14. **Kunal Lal, DDS, MS; George S. White, DDS; Dennis N. Morea, DDS; and Robert F. Wright, DDS.** Use of Stereolithographic Templates for Surgical and Prosthodontic Implant Planning and Placement. Part I. The Concept J Prosthodont 2006;15:51-58.

15. **Van Assche N, van Steenberghe D, Guerrero ME, Hirsch E, Schutyser F, Quirynen M, Jacobs R**. Accuracy of implant placement based on pre-surgical planning of threedimensional cone-beam images: a pilot study. J Clin Periodontol 2007; 34: 816–821.

16. **Loong Tee Yong, BDS, MDS (Oral and Maxillofacial Surgery), FRACDS; Peter K. Moy, DMD**. Clinical Implant Dentistry and Related Research 10(3):123-7 · February 2008.

17. **Natalie Y. Wong, DDS, Heather Huffer-Charchut, DMD, and David P. Sarment, DDS, MS.** Computer-Aided Design/Computer-Aided Manufacturing Surgical Guidance for Placement of Dental Implants: Case Report Implant Dent 2007;16:123–130.

18. **Philippe B. Tardieu, DDS/Luc Vrielinck, DMD/Eric Escolano, DMD**. Computer-assisted Implant Placement. A Case Report: Treatment of the Mandible (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:599–604).

19. **O. OZAN, I. TURKYILMAZ & B. YILMAZ** .A preliminary report of patients treated with early loaded implants using computerized tomography-guided surgical stents: flapless versus conventional flapped surgery Journal of Oral Rehabilitation 2007 34; 835–840.

20. **Hans-Joachim NICKENIG, Stephan EITNER** .Reliability of implant placement after virtual planning of implant positions using cone beam CT data and surgical (guide) templates Journal of Cranio-Maxillofacial Surgery (2007) 35, 207–211 r 2007.

21. **Ai Komiyama Bjo¨rn Klinge Margareta Hultin** .Treatment outcome of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning and flapless surgery Clin. Oral Impl. Res. 19, 2008; 677–685.

22. **Leonard spector** . Computer aided dental implant planning Dent Clin N Am 52 (2008) 761–775.

23. **David Schneider ,Pascal Marquardt ,Marcel Zwahlen and Ronald E. Jung A** .systematic review on the accuracy and the clinical outcome of computerguidedtemplate-basedimplantdentistry Clin. Oral Impl. Res. 20 (Suppl. 4), 2009; 73–86.

24. **U. S. Pal, Pooran Chand1, Neeraj Kumar Dhiman, R. K. Singh, Vimlesh Kumar.** Role of surgical stents in determining the position of implants Natl J Maxillofac Surg. | Vol 1 | Issue 1 | Jan-Jun 2010.

25. **Christoph Vasak, Georg Watzak, Andre ´ Gahleitner, Georg Strbac, Michael Schemper, Werner Zechner.** Computed tomography-based

evaluation of template (NobelGuidet)-guided implant positions: a prospective radiological study Clin. Oral Impl. Res. 22, 2011; 1157–1163.

26. **Curtis M. Becker, DDS, MSD, a and David A. Kaiser, DDS, MSD**. Surgical guide for dental implant placement THE JOURNAL OF PROSTHETIC DENTISTRY VOLUME 83 NUMBER 2 (248-252).
27. **Volkan Arısan, Z. Cuneyt Karabuda and Tayfun O zdemir**. Accuracy of Two Stereolithographic Guide Systems for Computer-Aided Implant Placement: A Computed Tomography-Based Clinical Comparative Study J Periodontol 2010;81:43-51.
28. **Ramasamy M, Giri, Raja R, Subramonian, Karthik, Narendrakumar R**. Implant surgical guides: From the past to the present. J Pharm Bioall Sci 2013;5:98-102.
29. **Chrcanovic BR, Albrektsson T, Wennerberg A** .(2014) Flapless versus Conventional Flapped Dental Implant Surgery: A Meta-Analysis. PLoS ONE 9(6): e100624.
30. **Romero-Ruiz MM, Mosquera-Perez R, Gutierrez-Perez JL, Torres-Lagares D**. Flapless implant surgery: A review of the literature and 3 case reports. J Clin Exp Dent. 2015;7(1):e146-52.
31. **Scott D.GanzDMD** .Three-Dimensional Imaging and Guided Surgery for Dental Implants Dental Clinics of North AmericaVolume 59, Issue 2, April 2015, Pages 265-290.

32. **Vercruyssen M, Laleman I, Jacobs R, Quirynen M**. Computersupported implant planning and guided surgery: a narrative review. Clin. Oral Impl. Res. 26 (Suppl. 11), 2015, 69–76.

33. **Rosen Borisov** .Radiological templates and cad/cam surgical guides. A literature review Journal of IMAB - Annual Proceeding (Scientific Papers) 2016, vol. 22, issue 3.

34. **Boyoung Ma, Taeseok Park, Inkon Chun, Kwidug Yun.** The accuracy of a 3D printing surgical guide determined by CBCT and model analysis J Adv Prosthodont 2018;10:279-85.

35. **CorinaMarilenaCristache and SilviuGurbanescu** .Accuracy Evaluation of a Stereolithographic Surgical Template for Dental Implant Insertion Using 3D Superimposition Protocol International Journal of Dentistry Volume 2017, Article ID 4292081, 9 pages.

36. **Michele Cassetta, DDS, PhD; Matteo Giansanti, DDS;Alfonso Di Mambro, DDS; Sabrina Calasso, DDS; Ersilia Barbato, DDS, MS** Accuracy of Two Stereolithographic Surgical Templates:A Retrospective StuDY Clinical Implant Dentistry and Related Research, Volume 15, Number 3, 2013.

37. **Saad A. Al-Harbi, BDS, MSci, and Albert Y. T. Sun, PhD** Implant Placement Accuracy When Using Stereolithographic Template as a Surgical Guide: Preliminary Results ISSN 1056-6163/09/01801-046 Implant Dentistry Volume 18•Number 1.

38. **Cassetta, Michele & Giansanti, Matteo & Di Mambro, Alfonso & Vito Stefanelli, Luigi. (2014)**. Accuracy of Positioning of Implants Inserted Using a Mucosa-Supported Stereolithographic Surgical Guide in the Edentulous Maxilla and Mandible. The International journal of oral & maxillofacial implants. 29. 1071-1078. 10.11607/Jomi.3329.

39. **Vercruyssen, Marjolein & Jacobs, Reinhilde & Assche, Nele & van Steenberghe, Daniel. (2008)**. The use of CT scan based planning for oral rehabilitation by means of implants and its transfer to the surgical field: A critical review on accuracy. Journal of oral rehabilitation. 35. 454-74. 10.1111/j.1365-2842.2007.01816.

40. **Yoon, Hong-Gi & Heo, Seong-Joo & Koak, Jai-Young & Kim, Seong-Kyun & Lee, Su. (2011).** Effect of bone quality and implant surgical technique on Implant Stability Quotient (ISQ) value. The journal of advanced prosthodontics. 3. 10-5. 10.4047/jap.2011.3.1.10.

41. **Venkatesh E, Elluru SV.** Cone beam computed tomography: basics and applications in dentistry. J Istanb Univ Fac Dent 2017;51(3 Suppl 1):S102-S121.

42. **De Vico, G & Ferraris, F & Arcuri, Lorenzo & Guzzo, F & Spinelli, D. (2016).** A novel workflow for computer guided implant surgery matching digital dental casts and CBCT scan. ORAL & implantology. 9. 33-48. 10.11138/orl/2016.9.1.033.

Annexures

ANNEXURE- I

RAGAS DENTAL COLLEGE & HOSPITAL
(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
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TO WHOM SO EVER IT MAY CONCERN

Date: 4.2.19

Chennai - 119

From

The Institutional Review Board,

Ragas Dental College and Hospital,

Uthandi, Chennai- 600119.

The Dissertation topic titled **"EVALUATION OF ACCURACY OF DENTAL IMPLANT POSITIONING PLACED USING DIGITALLY PLANNED 3D PRINTED SURGICAL STENT- A CASE SERIES"** Submitted by **DR.KISHOK. R** has been approved by the Institutional Review Board of Ragas Dental College & Hospital.

Dr.N.S.Azhagarasan, M.D.S
Member Secretary,
Institutional Ethical Board,
Ragas Dental College and Hospital,
Uthandi, Chennai – 600119.

ANNEXURE- II

URKUND

Urkund Analysis Result

Analysed Document: pliagrism check.docx (D47556676)
Submitted: 2/4/2019 7:30:00 AM
Submitted By: kishokrajkumar@gmail.com
Significance: 8 %

Sources included in the report:

EVALUATION OF OUTCOME OF SINGLE MANDIBULAR MOLAR TOOTH REPLACEMENT BY TWO NARROW DIAMETER DENTAL IMPLANTS.docx (D35006713)
LATERAL BONE CONDENSATION AND EXPANSION FOR PLACEMENT OF ENDOSSEOUS DENTAL IMPLANT IN DEFICIANT MAXILLA.docx (D34832186)
Digital Treatment Planning and Guided Surgery.docx (D29963919)
pliagiarism.docx (D34281776)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4681716/
https://idt.cdeworld.com/courses/5172-Surgical_Guides_for_Dental_Implant_Placement
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https://bmcoralhealth.biomedcentral.com/articles/10.1186/s12903-017-0441-y
https://www.sciencedirect.com/science/article/pii/0022391388902533
https://www.researchgate.net/publication/328940502_3D_Guided_Implant_Surgery_A_Case_Report

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